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THE METRIC SYSTEM — IS IT WISE TO INTRODUCE IT INTO OUR MACHINE SHOPS?

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Read before the American Society of Mechanical Engineers, Nov. 4, 1880.

The organization of a Society of Mechanical Engineers offers a convenient and fitting opportunity for the presentation of the views of a mechanical engineer on the subject of the metric system to members of his own profession and to those who are similarly interested. During the month of May, 1874, I had the honor of reading before the American Railway Master Mechanics' Association a paper on "The Metric System in our Workshop; will its value in practice be an equivalent for the cost of its introduction?" In that paper I treated the subject mainly in reference to its cost. From what has since been published by those who advocate the enforced substitution of the metric system for the weights and measures in common use in this country, it is evident that the subject will bear to advantage a different treatment. I now propose to supplement the question of cost by an endeavor to show that the system, *per se*, is not so well adapted to the wants of machinists as is the one now in use, and that its enforced introduction will do harm to our industries in place of doing good.

In addressing to the members of the American Society of Mechani-

cal Engineers arguments in opposition to any compulsory legislation in this direction, I feel that I am speaking to men who are familiar with the subject and who have already given thought to the results likely to obtain from the proposed change in the system. I feel, too, that I am speaking to those whose habit of thought fits them to consider the subject without bias; mechanical engineers, of all men using weights and measures, are the ones most eager to adopt what in the end will be of the most use. To them weights and measures are not abstract ideas, but tangible substances. Engineers make the machines for weighing and measuring, and the result of their use of those machines exists as fixed matter, costing millions upon millions of dollars.

To the great bulk of mankind engaged in trade, in buying and selling, in bartering and exchanging, it matters little what system they adopt; it matters little whether they are obliged to use a yard-stick or a metre-rod, pounds or kilogrammes, quarts or litres. The cost to them of a change from one to the other is the cost of the few devices needed in weighing and measuring; the *rationale* of the system may never enter their thoughts.

With the machinist the case is different. He must not only possess costly means of measuring and weighing, with a degree of exactness unknown to others, but the results of these weights and measurements are fixed and unalterable. Enormous expenditures on tools, on drawings, on patterns, on everything he uses in making or building his machines are on what is involved in the primary system used in determining weight and size. The product of this expenditure means everything that makes modern civilization possible. I propose, in this paper, to consider the subject only as it relates to our own profession; not in regard to its effect on the grocer, the dry goods man, or on the druggist. I propose to show why, after nearly twenty years' constant use of the metric system of measurement, I record my opposition to any enforcing legislation in this direction, because *the metric system is not well adapted to the practice of the machine shop.*

To render my arguments of any value I must endeavor to express myself so as to be understood by those who are not mechanics, and must crave the indulgence of my associates for dwelling, as I shall have to, on details so familiar to them and for making my explanation of the usages of the workshop so elementary.

For nearly twenty years one large department of Wm. Sellers &

Co.'s establishment has been worked on the metric system, as thoroughly as the system can be worked in any machine shop; as thoroughly as it is worked in France or Germany. The drawings made for this department are to the metric scale, figured in millimetres. The small tools and gauges are to metric measurement only, and the product of the shop is scaled to metric sizes and called by names based on those sizes.

During all these years, and for many years before, we have taken pains to inform ourselves, so far as lay in our power, as to all possible good to be derived from the system, in the drawing room as well as in the shop. We inquired into its defects and endeavored to overcome them by the same means as are resorted to in metric using countries. The system is urged by theorists as a perfect system. All nations, we are told, should adopt it to bring about a desirable unity in weights and measures, even if all cannot be made to speak our language and all cannot be equally good and pious, as measured by some international scale of goodness and piety.

The metric system was legalized here in May, 1866. Some of its enthusiastic advocates now urge its being made exclusive and obligatory. Societies are organized to teach its principles to the people, and much money has been expended in publishing, but up to this time few conveniences have been placed in the hands of mechanics to enable them to use it in their calculations. Some years ago (the conditions remain the same to-day) letters addressed to leading publishing houses asking for metric books in the English language, equivalent to those to which we constantly refer, which books are as necessary to us as are our other tools, failed to bring a single favorable answer. What was asked for, was some book in which formulæ shall be given in the most convenient form expressable in relation to the metric nomenclature. Many books can be found urging its merits as a system, and the writers of these, in showing (?) that the metric system can be learned entire in say fifteen minutes, may think they have done what is needed, but no book yet published in the English language, so far as I have been able to learn, even approximates to what is required. We have nothing like the hand-books published in German. These Germans, in teaching their people, gave side by side in these almanacs of mechanics the formulæ expressed in Prussian inches and in metres. When the year 1880 came around they dropped the Prussian inch from these books when it was possible so to do. There are many

very good books of tables for the ready conversion of the measurements of one system into the other, but unless an engineer is as familiar with the metric system as with his own they aid him but little. On the other hand, our English work books are many and valuable. The great bulk of literature of primary importance to mechanical engineers is in English and expressed in feet and in inches.

The absence of these help books need not, however, prevent any one *familiar with the metric system* from using it in his practice. If he can think in the new system he can work in it too. He can formulate what is directly needful to him if he will take the time and trouble so to do. The absence of these books has not prevented us from using it or familiarizing ourselves with it, and had it proved worth the effort, and possible, we would long ago have placed ourselves in position to advocate it, as none can knowingly do who have not tried it. In designing any engineering work, proportioned structures can be produced by either scale; the working drawings can be then made to whatever system obtains in the shop of erection. This change from one or the other system in the drawing room is a matter of no difficulty whatever. The change from one system to the other in the workshop, however, involves more than the usual advocates conceive of.

To show the measure of the misapprehensions as regards its effect on our profession, on the part of the enthusiastic advocates of the exclusive metric system, I will pass by some lesser lights and seek illumination from the central luminary.

Mr. Frederick A. P. Barnard, S.T.D., LL.D., who, besides being President of Columbia College, in New York City, is also President of the American Metric Bureau, and of the American Metrological Society, etc., etc., said, Dec. 27, 1877: "It is now little more than a dozen years since the movement in favor of the reform of the confused metrological system of the United States was set on foot. Originating with a few *advanced thinkers*" (the italics are mine) "and regarded with indifference by the multitude, it encountered, as it is the fate of all efforts to emancipate mankind from the burden of traditional evils, to encounter a much larger degree of opposition than of encouragement or favor." Then, after denouncing many of those who oppose the forced introduction of the system (see page 279 and elsewhere in his Metric System) says on page 283 of the same book, "Among the arguments urged by those who maintain the impossi-

bility of change only one appears to have much force, and that is the argument drawn from the dependency of machinery upon minute exactness in the measurements of parts and from the great expense which would attend the adaptation of machine shops and machines to a new system." Quoting the majority report of the Franklin Institute as to probable cost, and referring to the second report of the committee of the New York University Convocation, in which report the number of dimensions requiring separate indications on the drawings of a twenty-five-horse-power steam engine are given, he continues: "Singularly enough these statements, and all the rest of the same class in both the reports referred to, instead of being arguments against the abolition of the present metrological system and the substitution of the metric for it, afford the strongest reason for believing that that is precisely the thing which ought to be done. We desire, I suppose, to create a demand for our steam engines and our manufacturing machinery on the continent of Europe." * * * * "But a steam engine or a machine, all of whose parts are measured in English linear measures, if transferred to a metric country and there, by accident, disabled, becomes nearly useless, *since the shops of such a country afford no facilities for repairing it*," etc. (the italics again my own).

It seems needless to tell engineers that these statements show so entire an ignorance on the part of Mr. Barnard of the merits of the case as can scarce be credited from such a source. I feel ashamed to tender to him an explanation of what is involved.

The unit of measurement used in making a machine does not in any way complicate the repairs of that machine. Machines built in England do not always agree with any of our even sizes, yet this discrepancy is a matter of no moment in the repairs of any of them. If we fail to find sizes corresponding to our sizes in English machines, presumably built on the same scale of linear measurement as are our own, neither do we find even millimetre sizes, always, in machines from France or Germany.

Wm. Sellers & Co. make injectors for feeding boilers. They make them to the metric scale. They were doing so some years before Mr. Barnard's "few advanced thinkers" went into the metrological reform business. Their instruments are made from drawings figured in millimetres in all parts, except where screws and screw threads are needed. Screws to be cut on existing lathes cannot be conveniently figured

metrically, unless we adopt the custom of some German shops to figure in one dimension and make gauges to some other one. A screw bolt in Germany called 25 mm. diameter must be made 25·4 mm. size to conform to the screw system in use there; it will have 8 threads per inch and consequently 8 threads per diameter (I will explain this later). Screws cannot be metrically divided until metrically divided lead screws have been originated and put in the place of the inch divided lead screws *common to all lathes in all parts of the world.*

The people into whose hands these injectors pass know nothing of the scale of proportions to which they have been made. If some piece needs repairs and its shape has been lost by wear, it is needless to say that a knowledge of the scale would give no clue to that shape, but from some existing original any part can be copied; to copy requires no knowledge of the scale used. Repairs, too, as a rule, require deviation from original size to compensate for wear.

While the value of the unit of measurement may be of little moment in repairs, it is, however, all important in the first production of machines. This leads me to another misunderstanding on the part of those whom Mr. Barnard classes, I presume, with his advanced thinkers; this cleared away will bring us to the positian required in a judicious consideration of the two systems in their application to the machine industries of our country. I quote now from a pamphlet by Mr. Persifor Frazer; this pamphlet, says one of the Metric-Bureau tracts "contains more points, all well made, than any other of the same size on the subject." One of "the points" was suggested to him by the reading of a manuscript paper on the subject, said to have been written by an American engineer. The point made is this: "Lengths, breadths, thicknesses, capacities, and weights of things are related to the accomplishment of man's purposes and are varied to conformity with the inflexible laws of mechanics for different motors, strains, and materials; no change of system will alter in the least their dimensions, though it may give them different names." * * * "The grand truth of mechanics is, that the properties or dimensions of parts of machinery to accomplish any given purpose will be unaffected by any standard of length or weight applied to the part." This is a very good point, sounds well, but as the facts are not *exactly* as stated the point, is a dull one. No workshop in the land is or can be equipped with minor tools and gauges for the production of all sizes by *infinite* gradations. The calculated proportions of machines, the sizes indi-

cated by "the inflexible laws of mechanics," are sizes which must be made to conform to the nearest existing means of production and the merchantable sizes of the matter to be worked into shape.

In shop practice and in mercantile practice, to avoid an endless variety and confusion of sizes, certain dimensions in progressive order are adopted, being the sizes found most useful and most *salable* in practice. These progressive sizes we may call, in order to make the matter easily understood by "advanced thinkers" *Shop sizes* and *Merchant sizes.*

It is by the use of well considered ranges of shop and merchant sizes that the maximum of convenience is obtained at the minimum of cost. Hence one metrological system may be found to possess advantages over another when put to the test of practice. The one that is best in affording the most convenient and the most easily used and *memorized* series of sizes should not be called unphilosophical.

The resting place for memory in the American series of shop sizes is the inch. The inch is subdivided by a process of repeated halving down to $\frac{1}{16}$ in the usual grade of shop and merchant sizes, as in bar iron. This gives 16 sizes to the inch for small sizes; 8, 4, 2 or 1 to the larger sizes.

If a machinist should order from us a set of caliper gauges from $\frac{1}{8}$ up to 2, advancing by $\frac{1}{16}$, and from 2 up to 4 advancing by $\frac{1}{8}$, we are at once informed of the shop system contemplated in his workshop.

Calculations based on the "inflexible law of mechanics," as read by *finite man*, intimates for the size of a certain part of some machine a dimension 3·95 inches diameter, the prudent engineer has possibly assumed a sufficiently ample *factor of safety* to permit him to select $3\frac{15}{16}$ inches, the nearest shop size below the theoretical size, $3\frac{15}{16} = 3{\cdot}9375$ inches. He desires to use this shop size, because 4 inch iron, an obtainable merchant size of bar iron, will clean up from the black to this size; but if his dimension relates to castings or forgings he may select 4 inches as a shade stronger.

Metric using people have ranges of shop and merchant sizes too; when I come to compare their possible series and their actual series with our own some faint glimmer may come to those who now know nothing about the matter of the fact that our unphilosophic system is not so very bad after all.

In regard to what is involved in each shop size, in a money point of

view, I will give but one single example. The inquiry to our own tool-room keepers for a list of the separate devices used in producing one size, viz. 1¼ inch, brings to me the names of 129 articles or sets of articles, such as drills, reamers, gauges, boring bars and cutters, taps of all kinds for all sorts of uses, hardened mandrels, etc. etc. These many pieces, costing many hundred dollars, represent one size only. They tally with and belong to the dimension marked 1¼ in many thousand places on drawings, which have been accumulating for years, to patterns loading down our pattern lofts, to gear wheels interchangable over a continent, and to the out-put of our factory for years. So important in an economical point of view has come to be these shop size series, that machines built in one shop, if to be reproduced (not repaired) in another, must be redrawn to conformity to the shop system in use before the work can be begun to advantage. Year by year this harmony in shop sizes in America spreads over a larger area. Entire harmony in essential points exists in many of the leading shops. There are, however, examples still to be found in which machines built in one shop have no dimension in common with the shop sizes we use, as compared to our inch series or our millimetre series, *for we use both*. The expert recognizes such machines as having been built to gauges varied by the judgment of the master workman, or by the more *costly* method of fitting one piece to another already completed, a process not admissible in any well regulated machine shop.

A good workman may by hand construct, we will instance, a sewing machine. He will alter and try, and rearrange its parts until he has satisfied himself with the result. He may not have scaled this machine to any system. It goes to the manufacturer who must per force change some of the wild-cat sizes to conform to merchant sizes of the material to be used. For the rest he may be content to fit gauges and templates to the model and reproduce it in minute exactness. We recognize, however, in every well arranged series of shop sizes, and in the means employed to *maintain size*, the highest value of possible *merchantable* good workmanship, for in such possibilities we recognize economy in tools as well as in work, in interest on capital and in wages. This system has been growing year by year in spite of our so-called unphilosophic metrology. Eli Whitney, in 1798, gave a lesson in this direction when he began to make muskets with interchangeable parts in Springfield, Massachusetts, but it was not until 1855 that the English Government recognized what Whitney had

done by importing American gun-making machinery. Since Whitney's time, the standard system has been carried into all branches, not only of our own trade, but into all the requirements of other trades as well.

The metrology of the American shops is based on the inch, and on it only. This dimension is cut up into minor parts by halving to any degree of subdivision, practically in shop sizes to $\frac{1}{16}$; it is also divided into 10 parts and into 12 parts when such divisions serve any good end. All such divisions have their uses and lead to no confusion. The inch squared is the base of our strains and pressures. The inch cubed gives us capacities. Later, I will speak of 12 and 36 inches squared and cubed. This one unit, the inch and pound weight of 7000 grains Troy, is all that a machinist needs to carry on his business. His inch is the same inch as is used in England and in the Russian machine shops. His pound is the pound in common use in England.

In America we have dropped some needless weights and measures, just as we have seen fit to drop the letter u from some of our words. We do not use in the machine shop the ton of 2240 pounds nor its quarter or its hundred weight; we do use a weight called "ton of 2000 pounds." This is the factor weight in strains, and by it we sell machinery. Other trades may retain some of these useless things; I am speaking only of machine shop practice.

The unit of measurement in France and in Germany is the *millimetre*. It is not and cannot be the metre for the following reason: The great majority of all sizes used in the construction of any machine, whether it be big or little, are less than one metre. By the use of the millimetre only, decimals are avoided. 8 millimetres must be written 8 in the millimetre scale, while it must be written ·008 in the metric scale. This is reason enough, for by the use of millimetres only, confusion of signs is avoided, and the *danger incident to decimals* is also avoided, hence *all* drawings are figured in millimetres only, up to dimensions measuring many thousand millimetres. This little dimension is then squared and cubed, or ten or a hundred millimetres are squared and cubed, for the uses corresponding to our squared and cubed inch and foot. As may be expected, happy coincidences of conveniences are found in either system. Thus an ardent metric advocate instances that 1 kilo to the square centimetre is just one atmosphere. We say 15 pounds to the inch is an atmosphere. Neither one is right, but the 15 pounds to the inch is 1 per cent. nearer right than the other is.

For a machinist who seldom uses atmospheres a happy coincidence on the other side will be of more service. It so happens that wrought iron bars with parallel sides measure in square inches of this section just one-tenth of their weight in pounds per yard. Now, inasmuch as "shapes" in iron are rated by the pounds per yard, for convenience in large structures, so it comes to pass that, when we know the weight per yard of any wrought iron "shape," we know at once its sectional area. In as much as compression and extension and factors of safety are involved in a knowledge of cross section it is handy to be able to find it so readily, is it not? A shape iron, 80 pounds to the yard, has 8 square inches area of section. If it is good for 10,000 per square inch in extension we may load it with 80,000 pounds.

I have set out to compare the two scales—to compare the two units, rather, after an experience of twenty years with both. The inch is 25·4 times larger than the millimetre. These are the two dimensions we are to compare.

We will begin in the drawing room. Here "the inflexible laws of mechanics" find their first expression in form on paper. Few machines, or even parts of machines, can be drawn full size. Hence comes the need of "scales." There is reason in all things, even in scales. The unwritten law of most machine shops is to make every drawing as large as possible, as near full size as the nature of the subject and the dimensions of the paper used will permit. We have in our drawing room about 125 drawers, each of which will take in, without folding, drawings 52 inches (1320 mm.) long by 33 inches (840 mm.) wide. This is about as large a sheet as we can use to advantage, and tracings from these are not unmanageable in the work shop.

For metrical drawings we can use the following scales *only:*

Full size in which	1 mm. = 1 mm.
One-half size in which	½ mm. = 1 mm.
One-fifth " "	2 mm. = 1 cm. or 2 cm. = 1 dm.
One-tenth " "	1 mm. = 1 cm. or 1 cm. = 1 dm.
One-twentieth size in which	5 mm. = 1 dm.
One-twenty-fifth size in which	4 mm. = 1 dm.
One-fiftieth " "	2 mm. = 1 dm.

Down to the one-tenth scale the dimensions can be read from a good millimetre rule, for the one-twentieth, the one-twenty-fifth and the one-fiftieth scales must be constructed. The jump from one-half to one-fifth size is unfortunate. Could we conveniently quarter the

whole size we would have an increased area section, a matter of much moment. The $\frac{1}{4}$ of 10 inches is 2 inches, and the square of 2 is 4. The $\frac{1}{4}$ of 10 inches is $2\frac{1}{2}$ and its square is $6\frac{1}{4}$, a gain in size of over 50 per cent; a gain in comfort, in convenience and in eyesight. Here we catch the first glimpse of the advantage of our own system; for with it draughtsman can, from an ordinary well-divided inch rule, obtain the following scales: Full $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{6}$, $\frac{1}{8}$, $\frac{1}{12}$, $\frac{1}{16}$, $\frac{1}{24}$, $\frac{1}{32}$, $\frac{1}{48}$, $\frac{1}{64}$—12 gradations, as compared to 7, and to these 12 can be added with perfect ease 5 of the others, making 17 in all, if the preference be for the decimally divided inch, a scale carried in the tool box of every machinist, and obtainable from the two-foot rule in so common use.

The scale series in most common use is that of $\frac{1}{2}$, $\frac{1}{4}$ and $\frac{1}{8}$; this halves down from whole size and can be raised, in rapid drawing, by taking off diameter sizes from one drawing and using them as radius dimensions in the other, a process impossible between $\frac{1}{2}$ and $\frac{1}{5}$ sizes.

The true value of this extended series of scales, with its peculiar advantages, is manifest to any one familiar with both, *and admits of no dispute.* Is it a wonder that draughtsmen brought up under a metric rule take so kindly as they do to our unphilosophical system?

Drawing is but a small part of the engineer's work. More or less calculating has to be done; many hours must be spent in figuring strains, estimating weights, determining speeds and what not. This brings us to the test of convenience in calculation, to the stronghold of the metric advocates. It is just here that Dr. Edward Wigglesworth in his metric tracts comes out the strongest in his peculiar style. He says that Americans, self-ruling, are really too lazy, while merely claiming to be too stupid, to use the system. He says, "Shame on a country which to party gives up what was meant for mankind." It is claimed that the decimal notation of the metric rule gives great facility in calculating, but that this is not its sole advantage.

Mr. Frazer says: "Let the carpenter or mason be asked how many tons of water a structure, whose *external* (I guess he means *internal*) dimensions are given, by his rule, will contain, and they will acknowledge that the decimal division is not the only advantage of the metric system, but that another is the perfect relation of extension, capacity and weight." For a structure 5 feet square and 10 feet deep the carpenter would divide, in his head, 250 by 32 and say 8 tons, nearly, or 7·8125 tons exact of the tons of 2000 pounds in use, in all such measurements. The metric system would give for a nearly similar

structure, say $1{\cdot}5 \times 1{\cdot}5 \times 3$ metres, a result obtained by multiplying only; but what then? This problem applies to water only. If these spaces were to be loaded with bricks the metric multiplication must be still further multiplied by the specific gravity of bricks, thus: $1{\cdot}5 \times 1{\cdot}5 \times 3 \times 1870 = 12{,}622{\cdot}5$ kilos, while our mason's sum would read $5 \times 5 \times 10 \times 125 = 31{,}250$ pounds of common hard bricks, with an ease of calculation rather in favor of the two-foot rule.

I have mentioned the inumerable books which have been prepared, simplifying processes of calculations by tabulating the results of experiments on a basis of the inch unit. Of these books the English experiments form a large bulk of the valuable engineering knowledge of the world. Hodgkinson, for example, experimented with the crushing resistances of various substances, and the result of his experiments are in the possession of all engineers. He took samples in cylindrical form, 1 inch diameter, 2 inches long each, for these experiments. Armengaud quotes these experiments and tabulates the results, saying they were obtained by Hodgkinson, *avec des cylindres de* $0^{m}0254$ *de d*^{tre} *sur* 0·508 m. *de haut*$'' = 1'' \times 2''$, and from these he deduces, for example, that *ash* has a crushing resistance of from 610 to 653 kilos per square centimetre.

Mr. Trautwine, quoting Eaton Hodgkinson's experiments, also tells us that ash, weighing from 45 to 53 pounds per cubic foot, has a crushing value of 8600 pounds per square inch. Now, 1 pound per square inch = ·0703077 kilo per square cm., or 1 kilo per square cm. = 14·2232 pounds per square inch, $\frac{8600 \text{ pounds}}{14{\cdot}22}$ = about 605 kilos to the square cm. Here, from Trautwine's deduction, the metric using engineer will employ 605 as a factor where we use 8600 in the same case. He, because his unit of measurement is less, or, rather requires more figures to express it, multiplies these many figures by a lesser factor, while we, expressing our dimensions with lesser figures, use with these figures a larger factor. In other words, we can complete our calculation sooner because we are able to deal with the largest measures compatible with convenience. We can use the cubic inch, the cubic foot or the cubic yard, at our pleasure, just as the mechanic selects his tools in accordance with the extent of his work, and don't fool time away driving at a rail-road spike with a tack hammer.

I have before me, as I write, French books and German books on

mechanical engineering. In some, both French and German, all or nearly all, formulas for strains are expressed in kilos per square cm., while Prof. Reuleaux, in his many valuable books of reference, seems to adhere to kilos per square millimetre. Now, to test the matter of convenience, in a way familiar to all mechanical engineers, let us go to Reuleaux for our information as to the strength of cast iron, in the familiar equation for beams of $W = \frac{4\ s\ b\ h^2}{l}$. Reuleaux says the value of s may be taken as 4 kilos per square mm.; this equals 400 kilos per square cm., or 5689 pounds per square inch. Let our example be a cast iron beam of rectangular section, 9 inches deep, 4 inches wide, and 10 feet between its supports; given, to find its safe load in the middle. Let us round up these dimensions into a somewhat similar beam, measured in mm., $230 \times 100 \times 3000$. Now, $h = 230$ or 9, $b = 100$ or 4, $L = 3000$ or 120.

The formula then reads

$$\frac{4 \times 4^k \times 100 \times 230 \times 230}{6 \times 3000} = 4702^k \text{ for all dimensions, in mm.}$$

or

$$\frac{4 \times 400^k \times 10 \times 23 \times 23}{6 \times 300} \text{ for all dimensions, in cm.}$$

If we take 6 from the denominator, then

$$\frac{4 \times 66{\cdot}6 \times 10 \times 23 \times 23}{300}$$

If we make the formula good for cast iron only, and use centimetres in the numerator and metres in the denominator, which is the best we can do, $\frac{2{\cdot}664\ b\ h^2}{l}$ for cast iron $= \frac{2{\cdot}664 \times 10 \times 23 \times 23}{3}$.

Compare this with $\frac{4 \times 5689 \times b\ h^2}{6\ l}$ which reduces to $\frac{316\ b\ h^2}{l}$ for cast iron, and reads $\frac{316 \times 4 \times 9 \times 9}{10}$.

My note-books are full of such examples as this; it has been my wish to test this matter thoroughly; my experience covers many examples of engineers and draughtsmen educated in metric-using countries, who, when they come to us learn to use our measures as quickly as we can learn to use theirs, but adopt our methods of calculation as involving fewer figures. Thus, for all practical purposes, in strains, what

will be strong enough in kilos, if we assume two pounds to the kilo, will be near enough right, and if the "grand truth of mechanics is that properties or dimensions of parts of machinery to accomplish any given purpose will be unaffected by any standard of length or weight applied to the part," it is therefore possible to arrive at the theoretical proportion by either system, and it is presumable that the workman will select the easiest one to work with, the more so if the easiest one happens to be the one he has been most used to. I have yet to see the example of a metric-educated draughtsman working in millimetre calculations on an inch-measured machine, while with our own experience with both we could follow him in either.

Cubic inches go farther than cubic millimetres, *i. e.*, they involve fewer figures in their expression; because a cubic inch is 16000 larger than a cubic millimetre, it is 16 times larger than a cubic cm.; and while, again, the litre is may be 64 times larger than the cubic inch, yet is the cubic foot 27 times larger than the litre, and between the litre and the cubic metre there is no unit of measurement; 10 litres, like our gallon, has an edge only expressable in decimals.

The harmonious relation of extension, bulk, weight and all that comes out strongest when we deal with distilled water. Away from that precious fluid, and we are required to know and use the weights of matter as they relate to water. I must confess I see no difference in favor of hunting up in books the specific gravity of matter, or in looking for the weight of matter in pounds per cubic inch, or foot, or yard.

With distilled water engineers have little to do; when they note the solid matter accumulating in their boilers, they wish they had more to do with it. In hydraulic calculations the weight of distilled water, however, may be near enough to the weight of the water they have to deal with to enable them to reap all the advantages desirable from the system, did not the small units, the millimetres, or the many figures in the decimals of the metre, mar the result in a labor-saving point of view.

The value of the drawing room system is tested or tried when the drawings reach the machine shop. It is there that errors are found out. An incorrectly figured drawing costs nothing on account of the errors so long as that drawing rests quietly in its drawer; but it costs fearfully when the error is discovered in the partially finished machine. All engineers agree on one thing, viz., the fewest possible figures that

can be used to express dimensions clearly, the easier it is to work to the drawing, and the less liability to make mistakes. Beautiful as is a decimal system in calculation, and we all use it, save in mental arithmetic, it has been found advisable to avoid the use of decimals as far as possible on the drawings used in our workshops, even in metric using countries. A misplaced point is an easy error to make, and may cause no end of trouble and expense.

I had hoped for gain in the drawing room from the use of metric scales; I expected to find more than in the machine shop; I have been disappointed in both.

In the machine shop we come to test the value of shop sizes and merchant sizes, or rather the series possible in both, with one or the other system. For what is in use abroad, we look to Germany rather than to France for information useful to us, inasmuch as in Germany the metric system was taken up at a late day, and was introduced in its entirety without shock. To united Germany anything was better than their frightful confusion of 15 inches in use, all differing from the inch still used with their screw threads, and differing from the inch of England. The metric system is incomparably better than their before entire want of any uniformity. With us the matter is very different, as will be seen more clearly as we advance. We divide our unit, in practice, into just what parts are best suited to express our practical wants, and the system in our machine shops is uniform over a continent.

The first item of manufactured matter entering the machine shop door is bar iron. The merchant sizes of round, square, etc., in America, are by $\frac{1}{16}$, by $\frac{1}{8}$, by $\frac{1}{4}$, etc. In Germany, similar bars advance in size by 1 mm. up to 40, by 2 mm. from 40 up to 80, and by 5 mm. above 80. This system is memorizable by 40 and 80—by 1, 2 and 5. It is the best that can be done with a system tied up to an unhalvable scale. It does not agree with the English or American merchant sizes except in a few sizes. The system of bolts, diameters and threads per inch common or general over the continent of Europe is that known as the Whitworth system. They still adhere to this system as they do to the English system of gas and steam pipes and their fittings. The Whitworth system pitches its threads to even numbers or half numbers per inch in length. These pitches are easily obtained from the lead screws of all lathes, which are 2, 4 or 6 threads per inch as a rule. Having given up the inch, the Germans formulate their threads

per diameter (see tables at the end of this paper). For the names of the bolts, they must either retain their English names, and call a 25·4 mm. bolt one inch, or they must call it what it is, 25·4 mm., but some call it 25 mm., and make it ·4 mm. larger. This inch bolt has 8 threads per inch, and, as the diameter, too, is 1 inch, it can be said to have 8 threads per diameter. A $1\frac{1}{8}$-inch bolt measures 28·6 mm.; it may be called 29 mm. size; it must be cut out of 29 mm. iron, the nearest merchant size, with a loss of $\frac{4}{10}$ of a millimetre. This loss don't seem much, but the dies which have to cut it off tell the story very soon. The Whitworth scale gives the same pitch to $1\frac{1}{8}$ and $1\frac{1}{4}$ screws, viz., 7 per inch. The exclusive metric shops call the one $7\frac{7}{8}$ threads per diameter, and the other $8\frac{3}{4}$, and yet they are practically the same and must be cut with the same combination of change wheels on the lathe. Here is a precious example of what comes from trying to harmonize two systems under one nomenclature. The screw system in general use is so good, it has been so long in use, its disturbance would shock so many interests, that it is unwise to give it up, as unwise as it would be to adopt the American gas pipe system in place of the English, or for us, for sake of uniformity with England and Germany, we should attempt to force the adoption of their system into our houses.

Imagine the hue and cry if some "benevolent despot," for the good of mankind in general and Europeans in particular, should direct us to change our "fittings" to English standards, none of which would fit the pipes we have in our houses. Why, we are even vexed enough if we are sold a "sleeve" which will not fit a pipe put in place thirty years ago.

America has, for the last half century, been striving in its own way, towards equalization of its standard sizes. The immense railroad industries demand this. Standard wheels on standard axles—standard fit sizes for both—are all founded on an inch scale of sizes.

Standard shafting for mill gearing gives a good example. It has been demonstrated that bars carefully rolled to size in rounds can be reduced to turned shafting with the loss of $1\frac{1}{2}$ mm., or $\frac{1}{16}$ inch to the diameter. Hence, bars 2, $2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{3}{4}$, 3 inches, etc., are made into shafts $\frac{1}{16}$ less in diameter, sold by their full size names, *i. e.*, by the name of the iron from which they have been made and designated by the affix "shafting size." A 2-inch shafting size bar measures $1\frac{15}{16}$ inch, and a pulley ordered to-day with an eye to fit a $2\frac{1}{2}$ or a 4-inch shaft made

thirty years ago will be found to be to size. Now this American shafting sells freely in Europe and no one complains of its size. He can command the markets of the world who can make the best machinery at the least cost, and that machinery will be taken and used and no questions asked about its inches or its millimetres.

A scale of shafting sizes so uniform and so easily expressed by $\frac{1}{4}$ up to $3\frac{1}{2}$ and by $\frac{1}{2}$ inches to sizes above 3, is met in metric countries by the ease of an advance by 5 mm. only. To obtain the economy of American shops their shafting sizes should be $1\frac{1}{2}$ mm. less than their name, *i. e.*, a 100 mm. shaft should be made $98\frac{1}{2}$ mm. diameter, but the Germans have seen fit to retain even sizes and thus are obliged to use 57 mm. iron to make a 55 mm. shaft, and 93 mm. iron to make a 90 mm. shaft, while on still larger shafts they must be content to lose 5 mm. at each turning. Such is the usage now, so far as we can learn.

The shop sizes in America harmonize with the merchant sizes and with convenience. We cannot change them. It would be unwise, I think, to do so in face of the obtainable metric sizes if we could. One other example of good and bad systems, and I have done with this part of our subject.

An essential of all machine shops is a drill system; a series advancing by $\frac{1}{16}$ up to 1 inch, and by $\frac{1}{8}$ inch up to 2 inches, is equivalent to an advance by $1\frac{1}{2}$ mm. in a metric series. Such an advance as $1\frac{1}{2}$ mm. is impracticable, because it must be memorized entire; it affords no holding place for the memory. Twist drills were first made in America; they were so good, so useful, that American drills came to be the rage in Europe. After a time good makers there began their manufacture. I will mention one house, founded in 1834, that of Heilmann, Ducommunn & Steinlen, at Mulhouse (Alsace), one of the best known houses in all Europe. They make twist drills from 10 mm. up to 50 mm., advancing by 1 mm., but their price list tells us that the sizes marked in bold face type are the sizes in use in their own shop. These sizes are: 10, 12, 15, 18, 20, 23, 25, 28, 30, 32, 35, 37, 40, 42, 45, 47, 50. Here a series of sizes approximating the English ones is adopted, but it is a series which must be memorized entire, as its advance is not by two or by three either, in regular sequence. We cannot question the wisdom of the men who have selected these shop sizes to meet their known wants; they rank too high as workmen, they know too much to challenge criticism. Doubtless, this scale of

sizes is about the best they can do with the metric system; we would not tie ourselves to it. I could continue the list of practical difficulties until I had filled a volume. They run through the entire list of all that goes to make up the requirements of our profession, and show how unwise we would be to change, if we could do so for the sake of harmony with Europe. We have not adopted the Whitworth system of screws in America, and yet, by so doing, we would place ourselves in harmony with all Europe. We recognize objections to the system, and when those objections were clearly pointed out by Mr. William Sellers and he proposed a system free from the objections, his system was accepte l by the committee of the Franklin Institute and then by many departments of our government. Had the metric system shown itself to be the perfect system it is claimed to be, it too, would have been taken up more generally at a time when it was easier to have done so than now.

The American mind is quick to note what is to the advantage of American mechanics. We take up quickly what is good to hold to, and we will not accept what we have demonstrated to be less useful. This was made manifest to Prof. Reuleaux, Director of the Industrial Academy, Berlin, and is expressed by him in his report on motors and machines at Paris Exposition, 1867. In commenting on the many novelties from America he says, "Upon the whole it may be said that in machine industry England has partly lost her formerly undisputed leadership, or that she is about to lose it. The healthy young trans-atlantic industry, which continually withdraws from us energetic and intelligent heads and robust hands, makes, with the aid of her peculiar genius, the most sweeping progress, so that we shall soon have to turn our front from England westward." Then, in commenting on the rapidity with which American ideas were finding a home in Germany, speaks of the genius for inventions of this kind as peculiar to us—"They are distinguished from us by more direct and rapid conception. The American aims straightway for the needed construction, using means that appear to him the simplest and most effective, whether new or old." * * * "The American really constructs in accordance with the severest theoretical abstractions, observing on the one side a distinctly marked out aim, weighing on the other the available means or creating new ones, and then proceeding regardless of precedents, as straight as possible for the object." * * * "This spirit is strikingly

prominent in the (Wm. Sellers') system of screw threads which he has boldly placed alongside of the old venerated Whitworth system, in spite of the terror of its numerous adherents, after he had discovered actual deficiencies. A proper valuation of this proceeding contains the most instructive hints for our higher technical institutions."

There is an irreconcilable discord between the inch and the divisions of the metre. The inch has become fixed to a greater extent in dollars and cents, in fitness and convenience, in this country than in Germany, and yet there, in some cases I have shown, it cannot be given up. To keep our scale of sizes and use French dimension sizes would "furnish a precious example of the simplicity of the decimal system." I was a signer of the majority report of the Franklin Institute which opposed the compulsory adoption of the metric system. That report was prepared and written by the chairman, Mr. Wm. P. Tatham, since made President of the body which adopted it, as their view of the matter. Mr. Tatham is a man of culture and a hard student. His business as maker of lead pipes would have been less affected than that of almost any other manufacturer by the introduction of the metric system. He said, and I subscribed to the statement, that he believed that the ultimate benefits of the change proposed would be of less value than the damages during the transition. This was on the suppositious view that ultimately some would be benefitted. As an engineer I can see no possible good to come to American machinists from the change. Its introduction exclusively would not diminish his labor in any way; it would not cheapen his product, it would increase its cost. It is in fact, however, so impossible in view of existing matters and existing harmony in interchangeable matter, that should the metric standard be made the only legal standard in America to be used in buying and selling, the engineering establishments now in existence could not heed the law, but must perforce use their existing tools and gauges of precision, and continue to make material in conformity with existing matter.

The metric system was admitted here to an equal fostering in point of law in 1866. It had not been legalized in any way when we, for good reasons, introduced it into our own workshop in Philadelphia, and yet, at that time, we asked no one's permission to do what we pleased in the metrological management of our own business. We had a chance to try the system in making something which did not clash

with existing merchant sizes; once having perfected an organization in this department we became fixed in its continuance. Precisely the same reasons why we cannot change our general system into the metric hold against our giving up the metric system in the departments where it is in use.

If the change to the metric system will aid commerce, let the merchants do as we have done—try it. Commerce depends, in a large measure, on the possible out-put of our workshops. The engineer controlling the workshop and who, to be successful, must be a merchant too, knows too well how he stands to give up a practically useful system more convenient to him after having tried both, for the sake of any fancied conformity with other countries. He can give up no vantage ground. His success in his life-battle in these days of active competition depends upon wise economies to enable him to prosper. He has no more reason to cripple himself with an inconvenient system of metrology than he has to give up a tariff of protection on his production in order to make it easier for the world to compete with him.

I am tempted to touch on the educational view of the subject, but will content myself with very few words. When engineers are told that the change to the metric system would save two years, or one year, in the school life of every child, they ask how many years are now devoted to mathematics only, in the average four years' schooling of the mass of our boys, and ask, what is to be lopped off to make this saving? Many a good workmen who has risen to a high rank among educated mechanical engineers had too few years at school to admit of a month's saving in any one branch of his studies.

It is the thing just now to favor the change. A young engineer enlisting himself in the ranks of the metrical reformers (?) buys a cheap scientific notoriety. He is brought into sympathy with the self-constituted advanced thinkers. Those who oppose the change, after having become familiar with both, are said to "sever themselves from the congenial sympathy of the enlightened public opinion of to-day." The mechanical engineer can accept nothing as true until he has demonstrated the truth by experiment; at least, in anything capable of being put to the test of experiment. It is in the power of any intelligent man to test the metric system as others have done. He will, I think, find that the *savants* who originated the scheme before me-

chanical engineering, as it now exists, was known as a profession, made the mistake of beginning at the wrong end, the big end of the scale, the size of the world, and by the time they had cut it up or down to human wants it came out less fitted to human requirements than if they had recognized in the beginning the needs of the beings who were to use it.

Our metrological reformers urge us to adopt a new system in place of our present one, a system that harmonizes in no way with anything we now use. This new system is practically based on a certain measure over 39 inches long. This is cut up into 1000 parts, and 100 of these parts cubed gives their primary vessel of measurement. The contents of this vessel in distilled water under certain conditions is their pound weight. Had the English yard of 36 inches been so treated it would have been as good a system, but no better. It would have been as inapplicable comfortably to our profession as is the metric The wonderful extension of the metric system to time and infinite space was given up as impracticable long ago, and we are now asked to bear the shock of a mighty change to use this *inconvenient* system, this unhandy system of ten, for the sake of uniformity with some other peoples' of the world.

In conclusion, when we take into consideration the enormous interests involved in manufacturing in America; if it is, as we think, unwise to tamper with the existing metrology of our workshops, the question may well be raised as to the wisdom of enforcing the metric system in trade generally. The practical mind of Americans has already dispensed with much useless stuff, coming to us with our old metrology; is it not better to continue to amend what we have, to encourage the uniformity so desirable, rather than to attempt to make all things new; but in no respect practically better, at so frightful a cost?

WHITWORTH'S SCREWS.

In use in Europe, especially in Germany.

Diameter,—English Inch.	Diameter,—Prussian Inch.	Diameter. Millimetre.	Diameter at root of thread. English Inch.	No. of threads per Diameter.	No. of threads per Inch—English.	Diameter,—English inch.	Diameter,—Prussian inch.	Diameter,—Millimetres.	Diameter at root of thread. English Inch.	No. of threads per Diameter.	No. of threads per Inch—English.
1/4	0·243	6·4	0·186	5	20	2 1/4	2·185	57·1	1·930	9	4
5/16	0·303	7·9	0·241	5 1/2	18	2 1/2	2·428	63·5	2·180	10	4
3/8	0·364	9·5	0·295	6	16	2 3/4	2·671	69·8	2·384	9 1/2	3 1/2
7/16	0·425	11·1	0·346	6 1/2	14	3	2·913	76·2	2·634	10 1/2	3 1/2
1/2	0·486	12·7	0·393	6	12	3 1/4	3·156	82·5	2·857	10 9/16	3 1/4
5/8	0·607	15·9	0·509	6 7/8	11	3 1/2	3·399	88·9	3·107	11 3/8	3 1/4
3/4	0·728	19·0	0·622	7 1/2	10	3 3/4	3·642	95·2	3·323	11 1/4	3
7/8	0·850	22·2	0·733	7 7/8	9	4	3·885	101·6	3·573	12	3
1	0·971	25·4	0·840	8	8	4 1/4	4·127	107·9	3·805	12 7/12	2 5/8
1 1/8	1·092	28·6	0·942	7 7/8	7	4 1/2	4·370	114·3	4·055	12 11/16	2 5/8
1 1/4	1·214	31·7	1·067	8 3/4	7	4 3/4	4·613	120·6	4·285	13 1/16	2 1/4
1 3/8	1·335	34·9	1·162	8 1/4	6	5	4·856	127·0	4·535	13 3/4	2 1/4
1 1/2	1·457	38·1	1·287	9	6	5 1/4	5·098	133·3	4·790	13 13/16	2 1/8
1 5/8	1·578	41·3	1·369	8 1/4	5	5 1/2	5·341	139·7	5·020	14 1/16	2 1/8
1 3/4	1·700	44·4	1·494	8 3/4	5	5 3/4	5·584	146·0	5·238	14 3/8	2 1/2
1 7/8	1·821	47·6	1·591	8 7/16	4 1/2	6	5·827	152·4	5·488	15	2 1/2
2	1·942	50·8	1·716	9	4 1/2						

TABLE OF SCREWS.—By Reuleaux.

Diameter of Screw. d = mm.	Diameter at root of Thread. d = mm.	Threads per 10 mm.	Thickness of Head. Millimetres.	WHITWORTH'S.		
				Diam. of Screws. d = Eng. in.	Threads per 1 in. Engl.	Threads per length = diam.
6	4·1	7	7	$\frac{1}{4}$	20	5
8	5·9	6	8	$\frac{5}{16}$	18	$5\frac{5}{8}$
10	7·7	$5\frac{1}{2}$	10	$\frac{3}{8}$	16	6
12	9·5	5	11	$\frac{1}{2}$	12	6
15	12·2	$4\frac{1}{2}$	13	$\frac{5}{8}$	11	$6\frac{7}{8}$
18	14·9	4	15	$\frac{3}{4}$	10	$7\frac{1}{2}$
21	17·6	$3\frac{3}{4}$	17	$\frac{7}{8}$	9	$7\frac{7}{8}$
24	20·3	3	20	1	8	8
27	23·0	3	22	$1\frac{1}{8}$	7	$7\frac{7}{8}$
30	25·7	$2\frac{1}{2}$	24	$1\frac{1}{4}$	7	$8\frac{3}{4}$
34	29·3	$2\frac{1}{2}$	27	$1\frac{3}{8}$	6	$8\frac{1}{4}$
38	32·9	$2\frac{1}{2}$	29	$1\frac{1}{2}$	6	9
42	36·5	$2\frac{1}{2}$	32	$1\frac{5}{8}$	5	$8\frac{1}{8}$
46	40·1	$2\frac{1}{2}$	35	$1\frac{3}{4}$	5	$8\frac{3}{4}$
50	43·1	$1\frac{7}{8}$	38	$1\frac{7}{8}$	$4\frac{1}{2}$	$8\frac{7}{16}$
55	48·2	$1\frac{7}{8}$	41	2	$4\frac{1}{2}$	9
60	52·7	$1\frac{5}{8}$	45	$2\frac{1}{4}$	4	9
65	57·2	$1\frac{5}{8}$	48	$2\frac{1}{4}$	4	10
70	61·7	$1\frac{3}{8}$	52	$2\frac{1}{4}$	$3\frac{1}{2}$	$9\frac{3}{8}$
75	66·2	$1\frac{3}{8}$	55	3	$3\frac{1}{2}$	$10\frac{1}{2}$

TABLE OF AMERICAN AND ENGLISH GAS PIPES.

Nominal Diameter.	Act'l outs. Diam. in Engl. in.	No. of Threads per inch.	Act'l outs. Diam. in Engl. in.	Act'l outs. Diam. in mm.	No. of Threads per inch.	Nominal Diameter.	Act'l outs. Diam. in Engl. in.	No. of Threads per inch.	Act'l outs. Diam. in Engl. in.	Act'l outs. Diam. in mm.	No. of Threads per inch.
	U. S. Standard.		English Standard.				U. S. Standard.		English Standard.		
⅛	0·405	27	0·406	10·318	19	2¼	.....	.....	2·625	66·674	11
¼	0·54	18	0·531	13·493	19	2½	2·875	8	3·0	76·199	11
⅜	0·675	18	0·625	15·875	19	2¾	.....	.....	3·125	79·374	11
½	0·84	14	0·812	20·637	14	3	3·5	8	3·5	88·898	11
⅝	.....	.....	0·906	23·018	14	3½	4·0	8	3·937	100·01	11
¾	1·05	14	1·031	26·194	14	4	4·5	8	4·437	112·71	11
⅞	.....	.....	1·187	30·162	11	4½	5·0	8	.....	.....	.....
1	1·315	11½	1·312	33·337	11	5	5·563	8	.....	.....	.....
1¼	1·66	11½	1·625	41·274	11	6	6·625	8	.....	.....	.....
1½	1·9	11½	1·875	47·624	11	7	7·625	8	.....	.....	.....
1¾	.....	.....	2·125	53·974	11	8	8·625	8	.....	.....	.....
2	2·375	11½	2·375	60·325	11	9	9·688	8	.....	.....	.....
						10	10·75	8	.....	.....	.....

THE WEAKENING OF STEAM BOILERS BY CUTTING HOLES IN THE SHELL FOR DOMES AND NECKS.

By W. Barnet Le Van.

The weakening effect of cutting large holes in boiler shells for receiving steam domes or drums is well known among boiler makers, and in order to preserve as much as possible of the original strength of the shell they cut a hole much smaller than the diameter of the steam dome, with the idea that the shell is weakened only in proportion to the size of the hole cut, which is a great error. The weakening effect is proportioned to the section of the dome joining the shell, independent of the size of the hole cut.

The effect of an equal pressure upon both sides of that part of the shell covered by the dome is to deprive it of its direct acting tensile strength, in resisting an enlargement of the circle of the boiler, and substitute in its stead that resistance made by a curved plate pulled in the direction of its chord.

The plate of the shell at the base of the steam dome has the steam pressure on each side of it, and there is nothing to retain it in its arched shape; in other words, it is nothing more than a bent stay which the pressure of the steam tends to pull into a straight line.

As this is but an inconsiderable fraction of the tensile strength, the boiler is weakened in proportion. To make this good the boiler should be stayed, to compensate for the section of plate represented by the diameter of the dome. But better still is to have *no dome at all.*

It sometimes happens that from commercial considerations a dome is insisted on, and in the resultant conflict with the judgment and experience of the engineer, as is too often the case in making a plan for boilers, the latter has to submit. A steam dome is just such a case in point.

If domes are used at all, great attention must be given to the construction of them. They should be contracted at the lower part, and connected to the shell of the boiler by a neck of moderate diameter, and of such strength as to thoroughly make up for the cutting away of the shell of the boiler. I doubt the utility of steam domes under any circumstances, as they only act as a partial condenser of the steam passed into them.

Mr. Wilson says, without considering the cooling effect on the steam by the circumference of a large dome, exposed to the atmosphere, this would be a correct conclusion if the steam flowed slowly and quietly into the dome. But this is not the case with the engine at work, when the steam rushes into and through the dome with great velocity, and is liable to take a quantity of water along with it, causing the steam in the dome to be actually wetter instead of drier than the steam in the rest of the upper portion of the boiler.

Zerah Colburn says, "steam domes, if necessary, are necessary evils. They weaken the boiler materially wherever they are applied, also are very expensive. There are many locomotive boilers which have done and are doing well without domes, and with perforated steam pipes, taking steam along the whole length of the upper part of the boiler."

It is a well-established fact that a locomotive boiler gives off the greatest amount of power per square foot of heating surface. Now if locomotive boilers do as well without a dome, there is no valid reason why stationary boilers should not do well without them if properly proportionated.

Steam domes afford additional steam room, which may be desirable; but a simple calculation will show that by increasing the diameter of a 48-inch diameter boiler, 12 feet long, to 51 inches diameter, as much additional capacity will be obtained as is contained in two steam domes of the ordinary size (30″ x 24″), and the larger sized boiler, without the steam dome, will resist more steam pressure per square inch than the smaller boiler with the steam dome attached. By slightly increasing the diameter of the boiler it is hardly weakened, and the extra iron required will be but one-fifth that used in making the steam dome, saying nothing of workmanship, etc.

It is a well-known fact that steam domes, by exposing additional cooling surface, occasion a considerable loss of heat. This, although a minor objection when compared with others, is an additional reason why every effort should be made to substitute perforated pipes or some equivalent arrangement.

The Corliss Steam Engine Company, of Providence, R. I., do not use steam domes on any of the boilers supplied by them in their extensive business, and it is well known to every one what success they have had in the economical making as well as using of steam.

The New York and Erie Railway have a number of locomotives

without domes, and they carry their water as well as any locomotive boilers on the road.

Locomotives built by Corliss & Nightingale for the Cleveland and Pittsburgh Railroad, and having no domes, were reported to work as well as locomotives having steam domes.

In England and on the continent a large number of locomotives have been in use for a long time without domes. Notable may be mentioned the Great Northern Railway, from designs of Patrick Stirling, Locomotive Superintendent; South Eastern and the London, Brighton and South Coast Railways. On the latter road, from the designs of Mr. William Stroudley, Superintendent, in his boilers the longitudinal seams are all double-riveted, with butt strips inside and out, the latter being countersunk, to enable the rivets to fill the holes well up. The corners of the fire-box and also the fire-box casing are of large radius, that of the former being three inches, and that of the latter six inches. All the rivet holes in the boiler are drilled and all the edges of the plates planed. The man-hole ring is of sufficient cross-section to bring up the strength of the boiler at the man hole to equal that of the strongest seam. (*Engineering*, vol. 13, p. 91, 100.)

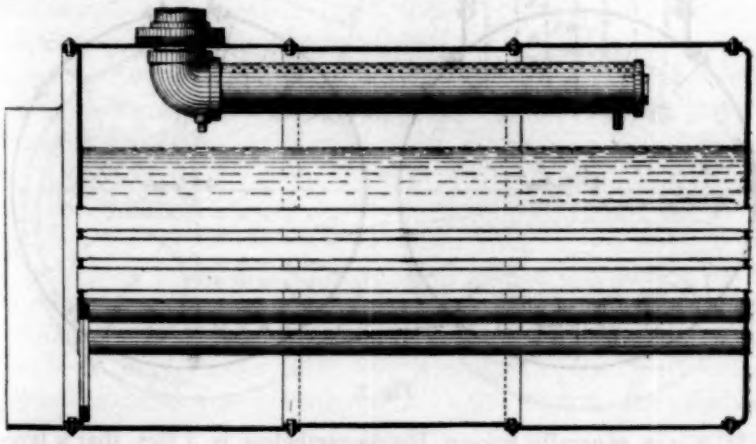


Fig. 1.

The Swiss North Eastern and the North Eastern Railway, of Switzerland, have no domes since 1872.

Russian locomotives, built by Messrs. Schneider & Co., Creûsot, France; Messrs. Kraus & Co., Munich; Glasgow and South Western Railway, Janes Sterling, Superintendent.

A substitute for a dome is a pipe placed inside of the boiler near the top of the steam space, the upper part of the pipe being perforated with small holes. The smallest holes should be made where the ebullition is greatest, which is over the fire-grate. It would require 250 holes of $\frac{1}{4}$ inch diameter, or 1000 holes $\frac{1}{8}$ inch in diameter, to give the area of a circular opening of 4 inches diameter.

Large steam pipes, containing more than one cylinder full of steam, tend to equalize the delivery of steam from the boiler, and thus to prevent priming. As there is no pressure on such pipes, they may as well be 6 or 8 inches in diameter as to be smaller.

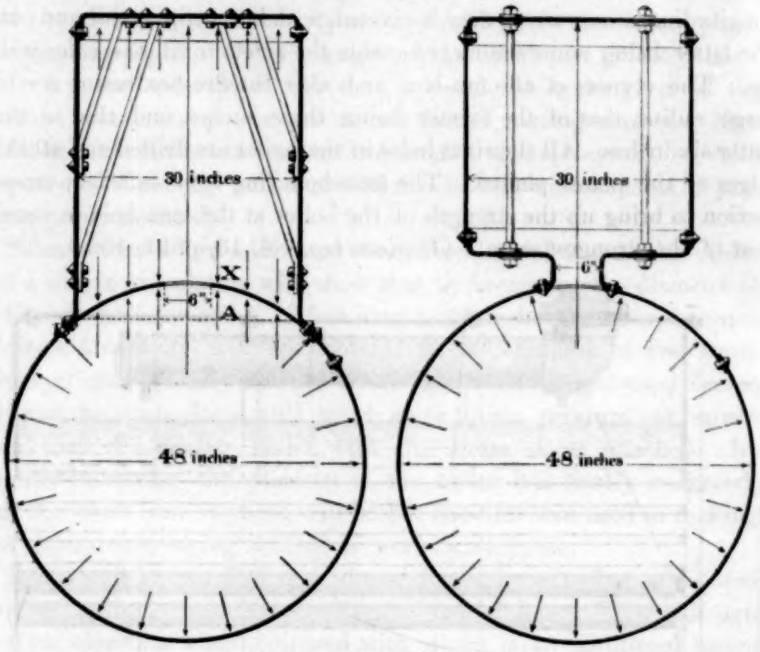


Fig. 2.

It is not generally known, but nevertheless is a fact, that a large number of boilers sent out are under internal strains, resulting from bad workmanship, which, no doubt, in some cases will equal the proproposed working pressure. These strains reduce the ultimate strength of the boilers independent of their being further weakened by cutting large holes for domes or necks.

The pressure in a cylinder boiler practically radiates from the axis

of the cylinder to the circumference, tending to preserve the circular form, and thus keep the plates of the shell in equal tension.

Now, when a steam dome is used with a small hole cut in the shell this effect is destroyed, from the fact that the instant the pressures inside and outside that portion of the shell plate covered by the dome are equal it becomes merely a bent stay, and affords but little strength to resist the bursting pressure on the shell of the boiler, having a tendency to become straight, as shown by the dotted lines at *A* (Fig. 2), and having no support from internal pressure to assist it in keeping a cylindrical shape, the pressure under and over the shell being the same as shown in the cut at *X*, causing the shell of the steam dome to be thoroughly strained and brought to a bearing, thereby stretching the boiler shell plates to the extent of their greatest elastic limit, and reducing its strength to a minimum.

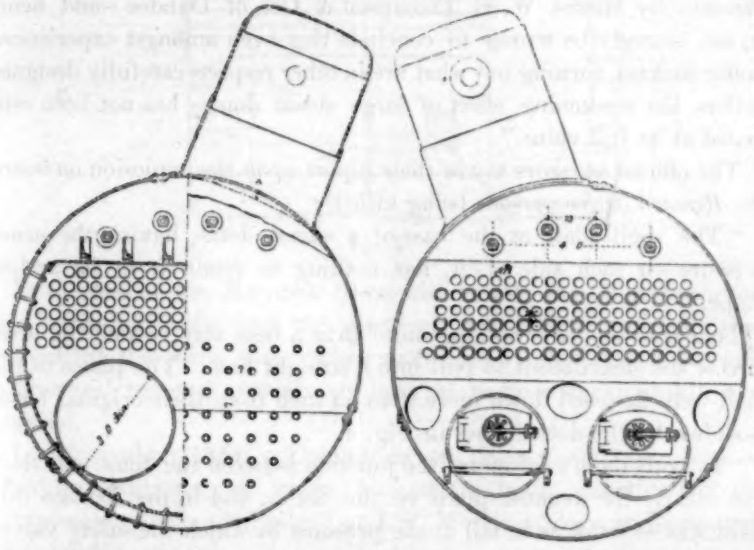


Fig. 3.

That steam domes are the cause of the weakening of boiler shells we have ample evidence. In England, on June 26th and July 1st, 1875, disastrous boiler explosions took place on board the screw steamers *Marcasite* and *Renown*. "The boiler that exploded was the one on the port side, and it gave way at the base of the cylindrical steam dome, which was attached to the boiler shell by a double row of

rivets, the plate of the dome being flanged, and the shell of the boiler beneath the dome left intact, with the exception of a man-hole cut in it." Fig. 3 represents the boilers of the *Marcasite*. The boilers in the two vessels were of similar construction, save that in the case of the *Renown* the steam dome was farther from the front plate, and was thus out of the uptake.

It is impossible to examine the cut without being at once struck with the weakness induced by the mode of attaching the steam dome —a weakness which is so justly remonstrated against in both reports on the explosion, as contributing so strongly to the disasters of these boilers.

The editor of *Engineering* says, editorially: "Yet the boilers were were made by firms of high standing—those of the *Marcasite* by Messrs. D. Adamson & Co., of Hyde Junction, and those of the *Renown* by Messrs. W. B. Thompson & Co., of Dundee—and hence it can scarcely be wrong to conclude that even amongst experienced boiler makers, turning out what are in other respects carefully designed boilers, the weakening effect of large steam domes has not been estimated at its full value."

The official assessors say in their report upon the explosion on board the *Renown* (three persons being killed):

"The shell plate at the base of a steam dome, having the steam pressure on each side of it, has nothing to retain it in its arched shape."

That is to say, it is nothing more than a bent stay, which the pressure of the steam tends to pull into a straight line. The plates of the shell were flattened down more than an inch from their original form, as shown by the dotted lines in Fig. 4.

"In both these explosions, the junction between the dome and shell was clearly the weakest place in the boiler, and in the *Renown* this point was so weak as to fail at the pressure to which the safety valves were loaded. Both disasters point strongly to the necessity of paying greater attention to the construction of domes, and to the desirability—if large domes are used at all—of contracting them at the lower part, and uniting them to the shell by a neck of moderate diameter, and of such stiffness as to thoroughly make up for the cutting away of the shell plate." In some cases, boilers fitted with large domes have been strengthened by straight stays placed across the opening from side to side and riveted to the shell. It is, however, almost impossible to so

apply these stays as to thoroughly compensate for the weakness caused by the application of the dome, while they give rise to a cross bending action at the points where they join the shell plates, which may, under some circumstances, lead to bad results.

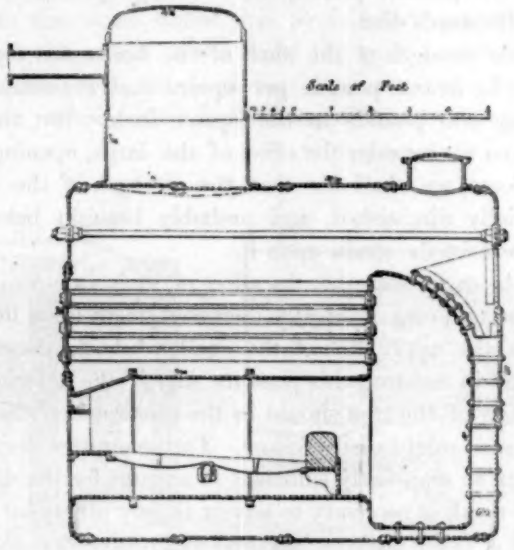


Fig. 4.

In the case of the *Marcasite* (three also killed), the Court remarked that it was imperative that the construction of boilers, especially that part called the *steam dome* (when such is used), should be most carefully considered and carried out, both as regards workmanship and material.

In November, 1851, a Committee on Science and the Arts of Franklin Institute, to whom was referred for examination the "Explosion of a Steam Boiler" at I. P. Morris & Co.'s, at Richmond, Philadelphia, report:

The boiler in question was cylindrical, 5 feet in diameter and 16 feet long, having a steam dome 4 feet in diameter, which was placed over an opening of the same size in the shell of the boiler. The iron was of the best quality, 0·3 inch in thickness, and was to be used under 100 pounds pressure. The parties who ordered it required that it should be tested under a pressure of 150 pounds. Upon this trial the fire was kept up until the safety valve lifted under a pressure of

148 pounds; an additional weight was then added, sufficient to give the requisite pressure of 150 pounds, and after a few moments the experiment was considered as satisfactory, and directions were given to open the fire doors. At this moment the explosion took place, killing one of the persons present and severely injuring two others, one of whom afterwards died.

The tensile strength of the shell of the boiler was found after the explosion to be 56,000 pounds per square inch of section, capable of withstanding 600 pounds to the square inch. But the committee says: "When we consider the effect of the large opening made into the steam dome, we shall see that the strength of the cylinder was very materially diminished, and probably brought below what was necessary to resist the strain upon it.

"It will be easily seen that the effect of such an opening thus covered must be to bring a greatly increased strain upon its edge where it intersects the upper line of the shell, while the dome itself gives but little aid in resisting this pressure, and if the deformation of the shape or a tear of the iron should be the consequence, the other result of the explosion might easily follow. The committee deem this defect of form to be so manifestly sufficient to account for the explosion that they do not think it necessary to advert to any other, *but strongly call the attention of boiler builders* (makers) *and engineers to the importance of avoiding such large openings in the shell in future.*" *

Man-holes and Necks.

All holes cut into the boiler shell are sources of weakness. (A man-hole should never be placed on the shell, if it is possible to get it into either head.)

This is best illustrated by a trial made by the Manchester Steam Users' Association, of Manchester, England, in 1876.

The association was asked to guarantee some of the "French," or "Elephant," boilers, analogous in construction to those in use in this city commonly called "Two-story," or "Righter," boilers (the latter being the name of the man who first used one of this form). Outside of a radius of 30 miles of this city they are scarcely known, and if the city of Philadelphia had never known them *there would be fewer widows and orphans.*

* The italics are our own.

The majority of boiler explosions in this city, and the most disastrous ones, can be attributed to this form of boiler.

Independent of their dangerous character, the efficiency of this form of boiler is much over-rated; the (steam) water evaporated by them only averages about seven pounds per pound of coal, and the steam is generally wet; this is, no doubt, due to a lack of proper circulation through the necks, which is shown by the violent oscillations of the water in the glass gauge, the level varying as much as six inches several times per second, when worked anywhere near their calculated capacity.

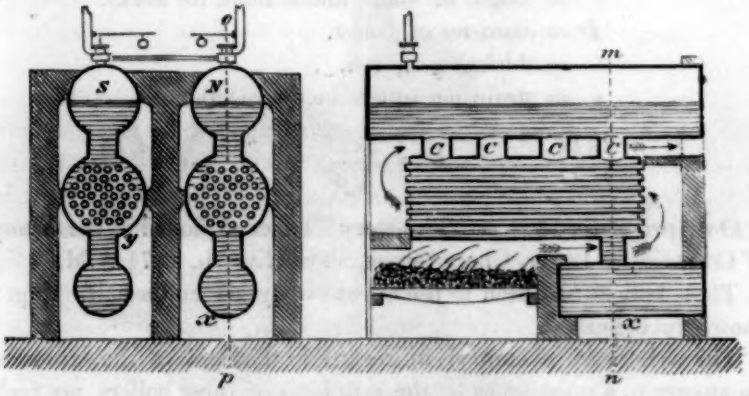


Fig. 5.

The last disastrous boiler explosion occurring in this city, from which four lives were lost, was a "Two-story" boiler, at the factory of Messrs. Wilt & Sons, which occurred June 29th, 1879.

To show the weakness of this form of boiler, I will state, for the information of those present, that the *factor of safety* recommended by the Franklin Institute, for the basis of estimate of the working strength of cylindrical surfaces of steam boilers should not *exceed* 6000 *pounds per square inch of section* (FRANKLIN INSTITUTE JOURNAL, August 16, 1873, page 142).

Or, in other words, the plates composing the shell of the boiler should not be subjected to more than 6000 pounds working pressure per square inch of section.

Now let us see how near this boiler corresponded to this.

The thickness of the iron in the shell containing the flues averaged 0·34 of an inch, the length of the shell being 144 inches (12 feet), of

which four holes, of 12 inches diameter each, or 48 inches, cut away for the necks, leaving only 144 — 48 = 96 inches by 0·34, equal 32·6 square inches, to resist a pressure of $\frac{144 \times 54 \times 80}{2} = 311{,}040$ pounds, which, divided by 32·6 = 9541 pounds per square inch, instead of 6000 pounds, as recommended by the Franklin Institute, an excess of $\frac{9541 - 6000 \times 100}{6000} = 59$ per cent.

p = steam pressure per square inch.
L = length of boiler, in inches.
l = length of boiler minus holes for necks.
D = diameter of boiler.
t = thickness of iron.
s = strain per square inch of section.

$$p = \frac{2stl}{LD} \qquad D = \frac{2stl}{Lp} \qquad s = \frac{LDp}{2lt}$$

On April 25th, 1864, a "Two-story" boiler exploded at the factory of Cornelius & Baker, Cherry street, above Eighth, at 7½ A.M.

These boilers had been in use about two years and a half. Fig. 5 shows the boilers.

The writer was examined in regard to the cause of the explosion. In answer to a question as to the safe form of these boilers, my reply was: "*I am of the firm opinion they are not safe boilers.*"

The jury, in their verdict, say: "With regard to the form of the boiler and its liability to explosion, your jury believe, from the weight of the expert evidence brought before them, *that this form of boiler is not safe,** and that, by excessive firing and even moderately low water (we mean before the water has fallen so as to uncover any of the tubes), the water can be driven away from parts of the tubes, laying them bare for a time, and that upon any slacking of the fire and the return of the water upon the tubes, an undue strain will be brought to bear on the boiler.

"We think that the boiler is constructed on erroneous principles, for the following reasons: Granting that the cylindrical form of each part gives strength, *the cylinders are materially weakened by the holes made for the connecting necks.** * * * * *

* The italics are our own.

"We do not think this boiler has any claims for economy to compensate for its complicated form, and we judge that a single cylinder boiler, partly filled with tubes, with the water-line in the same cylinder, would be at once safer and more economical than this form of boiler. We are aware that many of these boilers are in use, and we would urge the greatest caution in their management. They may be moderately safe when the boiler capacity is large as compared with the work to be done, but are not safe when the consumption of steam requires heavy firing to keep up the pressure."

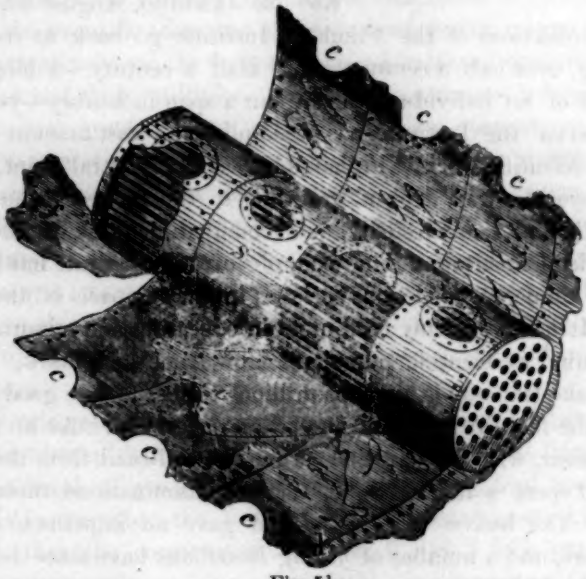


Fig. 5½.

The flue shell of one of the boilers was torn wide open through the *weakest point*, to wit, *the necks*, c c c, as as seen in the above cut, and the other boiler fell into the former, in which position it was found after the explosion, and is also represented by the cut.

A two-story boiler exploded Oct. 4, 1860, at Preston's mill, Manayunk, killing the fireman.

(To be continued.)

OBSERVATIONS IN BRAZIL.

By W. Milnor Roberts, C. E.

[The Committee on Publication has been favored with the following letter from a fellow-member of the Institute, who is perhaps as well and widely known as any one of his profession in the United States.]

Rio de Janeiro, August 30, 1880.

My recollections of the Franklin Institute go back to its modest beginning, over half a century ago. Half a century—a long period in the life of an individual, though but a span in history—yet in that brief interval the Institute has accomplished a vast amount of solid, practical scientific work. Philadelphia as the central point, and the civilized world, owe a debt of gratitude to the pioneers who labored so earnestly and disinterestedly, under many difficulties, in establishing the Franklin Institute. The example of the Institute has been followed by numerous analogous societies in various parts of the United States. It has now many coadjutors in educating and stimulating the popular mind to scientific pursuits. How true the remark, "A drop of ink makes thousands, perhaps millions think." One good example becomes the fruitful parent of an endless succession. As an instance, Prof. Agassiz, with his scientific corps, visited Brazil from the United States and spent a few years in scientific examinations through this country. The leaven thus introduced gave an impetus to scientific studies here, and a number of young Brazilians have since been educated in the United States, while others have been taught in the polytechnic schools, which are now flourishing in Brazil. The English language is constantly becoming more popular, although French, the polite tongue of Continental Europe, still predominates among educated Brazilians, while the general language is Portuguese. The French metric system was introduced in Brazil subsequent to 1865, and it has been universally adopted by the government and upon all public works, and it is already popularized and used generally in the daily business of the cities.

The writer, with hundreds of others, has for many years used the decimal system in nearly all calculations, and he has advocated the system as the best for money, weights and measures. Of late years,

the metric system, notwithstanding some drawbacks, has appeared to offer the only practicable solution of this problem for general use throughout the world. The system works well in Brazil, but it is not so easy to make it work well in the United States and in Great Britain. It has seemed to the writer that the time had not arrived for making this system compulsory, excepting in government service, though it is perhaps approaching.

We have exploded the pound, shilling and pence in the United States, but we yet retain a host of confusing weights and measures. The tendency is to simplify calculation, but there is still a contest between the scientific advocates of the decimal, metric system and those who so extensively use the long-established fractional quantities of feet and inches and their multiples. There is also a contest between friends of the metric system, some urging immediate compulsory laws and others opposing the compulsory feature. The writer stands with the latter class, believing that the change—so radical a change as it is—should be gradual. The world is becoming more and more homogeneous, and it seems inevitable that, in time, one system of weights and measures must prevail throughout the civilized globe. But enough on this subject, which has come up only incidentally, though it refers to an important change that has taken place in Brazil within a few years.

The metric gauge has been introduced into their railway system, upon a number of lateral roads and upon some main lines, thereby creating a break of gauge, which must be remedied at some future time. It is true that the features and circumstances of this country are such that the construction of their 5 feet 3 inch gauge tracks becomes very costly, making unprofitable investments. Only a few steam railways here earn a profit upon their cost, and that is obtained through transportation charges four or five times greater than the charges common on railroads in the United States.

Interior wagon roads, such as are common all over the interior of our country, here dwindle to mule paths not far back from the coast, and former undertakings to extend turnpikes or macadamized roads through the interior involved almost as much cost per mile as the cost of railways. Hence the metric gauge railway is now the popular mode of developing new regions. They also adopt a high per cent. of gradient and sharp curves, and then procure Baldwin locomotives to run upon the tracks. The general government is now paying out

yearly large sums for interest guarantees on costly lines, some of which do not pay running expenses. American locomotives, and to some extent American cars, have been adopted on several lines, but there are others where only English locomotives and cars are used. The Brazilians are willing to adopt improvements in any kind of machine and machinery when they become convinced that they are actual improvements; it must, however, be kept in mind that nearly all the capital and the bulk of the engineering in Brazil have been supplied from England. The government guarantee of 7 per cent. per annum was very tempting to British capitalists. The active business men of the respective provinces in Brazil are not more averse to the expenditure of government funds in their particular districts than are the same class in the United States, but, here the resources are much more limited, and there is a constant tensile strain upon the national credit.

A new Ministry came into power a few months ago, and it is understood that "economy" is to be the order of the day, but sometimes the "Chambers," the Senate and Assembly have power to bend good pecuniary resolves. Governmental economy is certainly good, but it is a scarce article in most countries, outside of the speeches and addresses.

Brazil has had no canal era; she passed at a bound from mule-paths to railways. Nearly all of South America is well watered by rivers, some of them of great size; among them the Amazon, by far the largest river on the globe, the Parana, the Orinoco and the Sao Francisco. As yet they are as nature left them, except that there are settlements at intervals along their banks, and steamboats are plying on the lower portions; and in the case of the Amazon and the Parana, and some of their large tributaries, they are navigated for hundreds of miles above tide water, but, as the regions are but sparsely settled, the river commerce is irregular, and more precarious than it is on the navigable rivers of North America.

The San Francisco river is a very peculiar stream, being divided by the immense Paulo Affonso falls—nearly two hundred miles from the ocean, into the lower and upper river—separated by seventy-eight miles of entirely unnavigable rapids and falls. The total descent at the Paulo Affonso falls is two hundred and sixty feet in about three-fourths of a mile. The quantity of water, even in the low stage of the river, is very great, being about thirty-five thousand cubic feet per second. And yet, during the entire season of 1879, none of the tributaries, within a distance of six hundred and forty miles, contained

any flowing water at their mouths. The valley of this river is subject to long-continued droughts, so that, excepting along the banks of the river, where the soil is annually overflowed, there is scarcely any cultivation in the immediate valley. In this respect the San Francisco is different from the other large rivers of Brazil, which, usually, are blessed yearly with sufficient rain-fall throughout their valleys; but the most remarkable peculiarity of this river is its long stretch of good navigation, embracing eight hundred and twenty-four miles above the rapids. It is a beautiful stream; from a-half to three-fourths of a mile in width, and generally of ample depth; abounding in graceful curves, and dotted with cultivated islands, the greater portions of which are covered by annual floods, which range from twenty-five to forty feet in height. In many cases the houses, or "shelters," on the islands are quite temporary, and only used after the subsidence of the floods, the people retreating to their more substantial houses on the main land when the river rises, as it does during the southern summer, in December, January and February. These "more substantial houses" are, however, as a rule, very humble edifices, built of sticks and mud, one-storied, with tile or palm leaf roofs, with a door and one window without glass, an earthen floor and hooks on the walls upon which the hammocks are hung, with an absolute minimum of furniture, yet the half-breeds and the full-blooded population of Indians and negroes seem to be contented and happy. The percentage of whites among the population, excepting in the towns, is quite small. Nearly all of the land available for cultivation along the margins and on the islands has long been occupied, but, owing to the great cost of transporting their products to a market at the sea-coast, they raise very little more than they consume. This river valley has been occupied by this class of people for a hundred or a hundred and fifty years in different parts. They are all Catholics, originally Christianized by the Jesuits, who built numerous churches on the main land and on the more elevated parts of islands, some of which are now merely picturesque ruins.

The government is constructing a metric gauge railway, seventy-two miles long, around the Paulo Affonso falls, to connect the Upper and Lower river commercially. Above the upper terminus of the railway there are about two hundred and sixty miles of impassable rapids. It was this portion of the river that the writer more particularly examined and reported upon in 1879. When this part shall be improved, as it can be at moderate cost, the people of the Upper river will have a

practicable outlet to the sea-coast, the river below the falls and rapids being always navigable for small-sized ocean-going vessels, drawing ten to twelve feet of water.

There are some thirty towns along the banks of the San Francisco, varying in size from one hundred to eight hundred houses, a majority of the buildings answering to the preceding description. In the larger towns there are a few fair houses—some *sobrados*, or houses of two stories, and some with glass windows. "Numerous poor people, and a few well-to-do" will apply to any town on the Upper river. A little money goes a great way—and the river-traders go after it, and get it.

There is one very noted church on the right bank of this river, one thousand and thirty miles from the sea, called the "Senhora Bom Jesus da Lapa." It was originally an immense, natural cavern, at the end of a very peculiar *serra*, or mountain, of bare limestone, which, with little labor, was transformed into the most curiously picturesque church imaginable. The serra itself is quite unique, being a mass of gothic pinnacles about half a mile long and two hundred to two hundred and fifty feet high. A natural opening in the side of the mountain was filled with a large window, which lights the interior in a weird manner. From the high, rocky ceiling clear, sparkling water, in several places, is constantly dripping upon the rocky floor, where it stands in little pools. Pilgrims, from places hundreds of miles off, visit this celebrated church and deposit their offerings, and many carry away bottles of the water, which they believe to possess miraculous properties. In one part of the cave there is white carbonate of lime, little pieces of which are obtained and taken away as a cure for sore eyes. Individuals of families make vows that they will visit this church, even though months may be occupied going and returning, in order to secure the smiles of "Our Lady" and bring good fortune to the family. It has been a nucleus, around which have clustered several hundred houses, and at times there are hundreds of pilgrims in the place, nearly all of whom travel on the river in canoes. This church is one hundred and fifty years old.

There has been a steamboat on the "Clear river," as it is called, above the rapids, for eight years, but in 1879, when the writer, by permission, took possession of it, it had not been run for three years, and it had never made but three partial trips. Practically, therefore, steamboating has not yet been established on the upper river, although it was proven by the writer's expedition in 1879 that it is navigable

for steamers for eight hundred and twenty-four miles, up to the falls of Pirapora, seventeen miles above the junction of the Das Velhas and San Francisco rivers, thirteen hundred and eighteen miles from the sea. This steamboat is built of iron, with side-wheels, ninety-eight feet long, fourteen feet wide, draws about four feet of water, and runs three or four miles an hour against a two-mile-an-hour current. It was carried, in pieces, more than three hundred miles across a wild country of miserable roads or mule-paths, and put together at enormous cost. It is not at all adapted to the river; drawing too much water and not having enough power. Light-draught, stem-wheel boats, such as have been for years used on the interior rivers of the United States, are the kind suited to the upper San Francisco.

At present, the commerce of the river is carried on chiefly in "barcas," boats from fifty to seventy feet, or even more, in length, eight to fourteen feet beam, and drawing from three to five feet when loaded. These are polled up stream and rowed down stream. They have four, six, eight, ten or twelve hands, according to the size of the craft. They start at day-light and stop at dusk. These river-men are active and strong and manage their vessels with great skill. The plainest possible description of running down through the rapids, fifty-five in number, when the river is in moderate flood, is not a little exciting. In the hands of a regular writing traveler, like Captain Barton, the rapids are rendered highly romantic and fearfully interesting.*

This river being within eight to twenty degrees of the equator, the climate is of course warm; but the nights are almost invariably cool and pleasant, and the early mornings are sometimes uncomfortably cold. There is a breeze nearly all the time, and on some parts of it the wind is disagreeably strong. Mountains are in view most of the way, and occasionally the mountain chains come to the river, adding greatly to the beauty of the landscape; though there are intervals where only flat or very gently rolling land is in sight. The writer was several times strongly reminded of scenes along the Delaware, between Philadelphia and Trenton—with the buildings and fences omitted. The fencing between the little plantations on the river banks is of a very primitive character. Timber is scarce. The river abounds with very fine fish, different from any with which we are familiar in the United

* The writer's description of these rapids fills many pages of very dry reading, although they are all about running water.

States. There are also alligators, not of large size, generally five to six feet in length. River-hogs are quite common; and there are some otters, and beavers. Game, excepting ducks, is not very abundant. Snakes flourish well, though we saw but few alive. Monkeys are rather rare, immediately along the river; but flocks of parrots are numerous, and there are some fine singing birds. There are ostriches, and their eggs are good food. There are Brazilian tigers; but they are not numerous.

There are mountain masses of excellent iron ore, at several points along the river; and good limestone is convenient; but fuel is scarce, till the upper part of the river is approached. No coal has yet been discovered along this valley. Salt is manufactured in a crude way, on a small scale, at the little farms or plantations, by leaching the saline, alluvial earth, and then evaporating the water; but their best salt is imported from the coast, and carried by pack-animals hundreds of miles. At seasons when the river is in a good stage, some salt is packed across by land from the lower to the upper river, and shipped up the river in boats.

The two great confluents, the Das Velhas and San Francisco, have courses of about five hundred miles each above their junction, so that the total length of the main river is over eighteen hundred miles.

The Das Velhas has been navigated by another very small steamer, during a favorable stage of the river for several hundred miles, though the stream is much obstructed by rapids, but no steamer is now running, the small trade of the river is carried on by canoes and *ajojous*, or double canoes. The San Francisco, above the Falls of Pirapora, is much more obstructed by rapids, and its still smaller trade is confined to canoes.

Most of the region above the junction is mountainous, and covered with true forest, the chief settlements having been made in consequence of the working of the gold mines, which have been wrought many years. There are diamond workings also, but they do not yield so well as formerly.

There is always a sufficiency of rain for agricultural purposes in this upper region, and the soil is good, though during half the year the weather is very dry, but the upper streams never cease to flow, and in the lowest stage the quantity of water is large.

Excepting the necessities of the gold and diamond districts, there has been no inducement for extensive cultivation of the soil on these

upper waters on account of their great distance from the coast market.

The "Dom Pedro Segrenda" Railway is reaching out toward this region by an extension. Quite recently it was opened to Barbecena, about three hundred miles from Rio de Janeiro, a point within a hundred miles of the head waters of the San Francisco.

Since the Emperor's visit to the United States, in the Centennial year, during which he made numerous observations all over our country, he is more than ever inclined to encourage the development of Brazil, not only by railways, but by the improvement of her rivers and harbors, but at the present time the resources of Brazil are so tied up by obligations previously incurred that not much can be applied in new directions. Coffee and sugar are the two principal products; cotton, since the United States resumed its supremacy as a cotton raiser, has not been very profitable here, and but little is now grown.

Slavery still exists, although by an Imperial decree all children born of slave parents, since 1871, are free. Many years must elapse, as the law now stands, ere Brazil would be free, but it is more than probable that other laws will be enacted hastening the period. An effort has been made (by the late ministry) to inaugurate a system of Chinese coolie labor, and an ambassador was sent to China for the purpose of negotiating some arrangement in that connection. It will fail, either in its incipiency, or in its trial, if ever tried. The slave owners must teach their slaves how to be free. Brazil is not a country to "settle up" by immigration, like the United States; the introduction of a foreign population into this country is destined to be only very gradual.

Spanish Engineering.—The success of Director-General Ibanez, in his Spanish triangulation, has led to applications for his assistance in other fields of labor. He has lately visited Paris on business connected with the international committee of weights and measures, of which he is the president, and he is about going to Switzerland to make the necessary preparations for the measurement of a base line with his apparatus. This arrangement is the result of diplomatic negotiations between the Swiss and Spanish governments, and it involves a permission to employ such members of his engineering corps as Senor Ibanez may desire. The Spanish journals manifest a justifiable pride in the honors which have thus been conferred upon one of their leading engineers.—*La Gaceta Industrial.* C.

MODERN STEEL AS A STRUCTURAL MATERIAL.

By W. Worby Beaumont, C.E.

Read at the Meeting of the Society of Engineers, England, October 4, 1880.

The object of this paper is not to bring forward any new experiments on the properties of steel as employed in constructive work, but to invite discussion upon a few points which may occur to the engineer to whom it seems desirable to consider the relative advantages of mild steels and iron in some mechanical or constructive work. For several years the substitution of steel for iron in various structural work has occupied the attention of engineers and metallurgists, but the progress which has been made, compared with the hopes that were entertained when steel made by the Bessemer process became cheap enough to make its cost strength for strength comparable with that of iron, has not been great. There are classes of structures in which a reduction in weight would be a material advantage, even when attended with an increased total cost. In this direction, therefore, engineers turned their attention, with a view to the application of steel. The difficulties, however, which attended the manipulation and connection of steel in structures largely composed of plates checked its application. Many failures attended the attempts to use it, chiefly resulting from apparently anomalous behavior of the metal under what were considered similar conditions, but more, perhaps, owing to the special treatment which it required as compared with iron. Those who had been long accustomed to the manipulation of iron were unable to depart from past practice sufficiently to operate upon the new material with all the careful attention to its different properties which these demanded. Thus, although the difference in its behavior in the hands of the smith and plate worker, as compared with iron, was considered in several of the details of manipulation, certain other peculiarities were lost sight of in the assemblage of parts, which resulted in the destruction of work when almost completed. Even twenty years ago, before the modern cheap steels had been offered, steel made by the crucible process had been successfully employed on a small scale for boiler work. Very careful attention to the behavior of steel under treatment had no doubt been observed, as it might easily be on a small

scale; but when, some years after, attempts were made to use Bessemer steel for boiler and bridge work, difficulties arose, some of which were attributed to the nature of the material and some to the want of thorough care on the part of the workmen. Even when plates of this material cost more than iron for boiler construction, and very much more than iron for bridge and girder work, attempts were made to use it for the latter on account of the several advantages which would arise from a decrease in the permanent load of bridge structures. Failures, however, of parts of these structures, both before and after completion, due to the want of the observance of the special treatment which the material demanded, discouraged its employment. The endeavors of steel makers during the past few years have, therefore, been directed to the production of steel possessing properties so far similar to wrought iron that no great departure from the methods of working this material need be made. Apart from the frequent want of uniformity in the mechanical properties of the Bessemer steel plates of a few years ago, it generally exhibited an absence of toughness, which not only made it difficult of manipulation in the hands of the plate smith, but caused its destruction after being built into a structure. Its uncompromising rigidity rendered it incapable of accommodating itself to, and gradually eliminating from, itself, the residual strains originating in unequal heating and cooling, and also to the unequal strains visited upon it by other parts of a structure, of which it was made to form a part, either by riveting or other modes of connection. It was not that the steel did not appear to possess the qualities when tested in the testing machine, but its behavior was apparently different when employed in full size pieces or plates, from that exhibited when tested in small pieces in the machine. This difference indicated that there were differential internal molecular strains resident in the whole plate, which were eliminated when the same plate was cut into strips. This elimination, it was considered, could not take place in the whole plate on account of the harshness of its material. Annealing was resorted to, but only with partial success, the complex nature of the strains in a plate of the material, even when cooled slowly, being sufficient, when aggravated by extraneous strains, to cause its rupture.

The necessity of imparting to steel plates the toughness characteristic of good wrought iron has thus induced steel manufacturers to devote their attention to the production of steel possessing great duc-

tility. It is on this point that much might be said, because in the search for toughness the advantages which the employment of steel in some structures seemed at one time to promise, are being almost lost sight of. Not only are these advantages likely to be lost, but the great ductility being imparted to soft steels and ingot iron in search for this necessary toughness seems likely to give us a material inferior in some essential qualities to much of the wrought iron hitherto in use. Toughness in plates has not been obtained, but instead thereof great ductility attended with low elastic strength. It cannot be disputed that there are large quantities of mild steel plates produced which will stand all sorts of tests, necessary and unnecessary, and behave better in manipulation than even the best wrought irons. Such mild steel plates have many applications, but for many engineering purposes they fall very far short of the structural value of plates which might be fitly designated steel, in the sense in which that term was used a dozen years ago, when cheap steel promised to aid the engineer in reducing structural weights.

It may be premised that the structural value of a metal will be proportionate to the degree in which it combines high ultimate strength with high elastic limit and wide range of elastic and ductile extension, or in proportion to the relation in which it combines toughness with strength. Thus a metal which possesses high ultimate strength and high elastic limit with small ranges of extension, will not have great structural value, as it will not be capable of withstanding impact strains. Again, a metal possessing high ultimate strength with low elastic limit will have small value for structural purposes, as, though high ultimate strength is an essential property, the limit of elasticity determines in almost all cases the sectional area, and, therefore, weight of metal required for a given duty. A high elastic limit, with considerable elastic extension, must be obtained, combined with great toughness beyond that limit, or in other words, a high elastic limit must be attended by a considerable range of extension both within and beyond that limit, combined with high ultimate strength.

The tendency, however, in the production of the modern mild steels and ingot irons, which will eventually no doubt supplant wrought iron made by the puddling process, is to make a metal which is far from combining these properties in such relations that it is best suited for structural purposes, or so as to offer those advantages which were at one time supposed to be attainable by the use of steel.

The best index to the comparative structural value of different materials is probably that obtained by the application of Poncelet's formulæ as simplified and made applicable for practical purposes by Robert Mallet. This formulæ expresses by coefficients $\frac{Te \text{ and } Tr}{Te^1 \text{ and } Tr^1}$ the work done by an extending or compressing force upon an elastic prismatic body, at the point where its elasticity becomes permanently impaired, and its form distorted, and at the further point where rupture occurs, or, in other words, it expresses the balance in any material between strength and toughness, and was designed to give a more exact index to the structural value of materials than was given by the early experimenters down to the days of Telford, when the force necessary to produce rupture was alone considered. The formulæ are probably known to most of the members of the Society, having been given by Mallet in a paper "On the Coefficients of Elasticity and of Rupture in Wrought Iron," published in Vol. XVIII of the "Proceedings" of the Institution of Civil Engineers, and subsequently employed by Dr. Pole in his book on "Iron as a Material of Construction," but they may be repeated here.

Let L = the length of the prism;

l = the unit of length;

A = the transverse sectional area of the prism;

i = the extension, or compression which is proportionate to $\frac{l}{L}$;

P = the force of extension or compression which is proportionate to A; and

e = the elastic resistance which balances P, or the modulus of elasticity.

The force P is, of course, variable between o and i,

$$i = \frac{P\,L}{e\,A} \text{ and } P = \frac{e\,A}{L}\,i.$$

If x be any small extension, or compression less than the nth part of i, P corresponding to $x = \frac{e\,A}{L}\,x$. The work done in extending, or compressing through the infinitely small additional range $\Delta^1 x$ (assumed uniform) $= \frac{e\,A}{L}\,x\,\Delta^1 x$, and the whole work done when i = the

compression or extension at which the elasticity of the material is permanently changed, or the elastic limit reached, is

$$Te = \frac{e\,A}{L}\int_0^i \frac{i}{o}\,x\,dx = \tfrac{1}{2}\,\frac{e\,A}{L}\,i^2,$$

$$\text{or } Te = \tfrac{1}{2}\,e\,i^2, \text{ or simply} = \tfrac{1}{2}\,Pi;$$

for the unit of length and section. The value of the coefficient *Tr* is arrived at in the same way, by substituting the corresponding values for *P* and *i* due to the moment of crushing or of rupture. Thus for a material having under tensile strain an elastic limit *P* of 12 tons per square inch, an elastic extension *e* of 0·02 inch in a foot of length, and having an ultimate of 22 tons per square inch and a total extension of, say 1 inch, the coefficient

$$Te = \frac{P \times 2240 \times \frac{e}{12}}{2}, \text{ or}$$

$$Te = \frac{12 \times 2240 \times \frac{0{\cdot}02}{12}}{2} = 22{\cdot}31$$

$$\text{and } Tr = \frac{22 \times 2240 \times \frac{1{\cdot}0}{12}}{2} = 2052{\cdot}5$$

while another material having an elastic limit of, say 14·22 tons, elastic extension 0·024 inch; ultimate strength, say 23 tons, and total extension of 1·6 inch in a foot, the coefficient *Te* = 31·8 and *Tr* 3501.

In order to determine the relative structural values of several materials, it is thus necessary to take *Te* and *Tr* simultaneously into consideration, though *Te* is the coefficient of the greater importance in most structural work.

About a dozen years ago Bessemer metal was offered for bridge and ship construction which in the testing machine showed an ultimate tensile strength of from 34 to 40 tons per square inch, an elastic limit from 20 to 26 tons, and a range of ductile extension of from 10 to 18 per cent., while the tests of plates considered suitable for the shells or barrels of boilers showed figures not much lower than these. The failures which occasionally attended the application of this steel, however, discouraged the extension of its application by engineers, who hoped that greater uniformity in the mechanical properties of the metal would gradually be obtained by the steel makers. A steel of

somewhat lower tenacity and greater ductility, attended by greater uniformity in composition and behavior, was then produced, and this indicated that steel makers and engineers must look to steel of milder character for the removal of the difficulties which had attended the structural application of cheap steels, that is steels not produced by the crucible. The result of this was that engineers specifying steel for, say, bridge work stipulated that it should not possess more than a certain maximum tenacity, a reversal of the stipulation that had always and does obtain with respect to iron. As a further result of this, and to ensure that the harder steels of comparatively high tenacity, but less uncertain character, should not be used in the construction of bridges, the Board of Trade regulations upon the subject limited the tensile strain on any part of a structure to 7 tons per square inch. This has led to the endeavor on the part of all steel-makers to produce the very mild soft steels now largely used, some of which affords the engineer no help towards producing the lighter structures which a dozen years ago it was promised that steel would give them. Boiler shells must be made nearly or quite as thick as if they were constructed of iron.

As an instance in illustration reference may be made to the results of a series of experiments made on iron and mild steel, in order to determine their respective values for high-pressure boiler construction, and described by Mr. David Greig and Mr. Max Eyth in a paper read before the Institution of Mechanical Engineers, in June, 1879. Amongst other experiments, the mechanical properties of mild steel and Yorkshire plates under tensile strain were determined. The plates—both iron and steel—were obtained from Messrs. John Brown & Co. and Messrs. Cammel & Co. In the paper referred to the mean tensile strength, elastic limit and extension are given as follows:

	Ultimate strength. Tons per square inch.	Elastic limit. Tons per square inch.	Extension per cent.
Iron plates, . .	22·27	16·06	36·2
Steel plates, . .	25·80	16·74	28·3

The extension given is in a length of 6 inches. If all reference to the secondary elastic limit, which may be induced by repeated application of strain up to and slightly exceeding the elastic limit of each preceding test, be omitted, it will be seen that the so-called steels, to which the above figures relate, present scarcely any structural advantage over iron. The elastic limit is nearly the same, and though its

ultimate strength is greater than that of the iron, its ductility, as shown by its range of extension, renders its greater ultimate strength of little value, for very long before it can be strained to that limit in any structure, it stretches so much that the accumulation of strain is prevented and this may be shown to take place in bridge as well as boiler structures. With respect to the latter, Messrs. Greig and Max Eyth observe that "the tensile and shearing strength of the material supplied for these tests by some of the most experienced makers of steel, and by them, no doubt, considered the best for the purpose, has in the experiments proved to be not more than 10 per cent. above that of the iron supplied at the same time, and its want of hardness, as distinct from tensile strength, has proved to be a very serious disadvantage in boiler work. What the trade now requires is a return to a harder material of increased tensile strength without losing the homogeneity which is at present obtained at the expense of hardness." Again, in speaking of the results of the test, under hydraulic pressure, of the complete boilers made of this steel, they say "the compression of the rivet and elongation of the rivet hole resulted invariably in leakage which prevented the necessary pressure from being obtained. Each rivet became its own safety valve, and the strain put on the weakest part never reached more than 70 per cent. of the breaking strain. This is the point where additional hardness of the material would be most useful, as it would prevent the opening of the rivet holes, which now makes a boiler useless long before the breaking strain is reached." This evidence is, therefore, to the effect that no structural advantage is obtained by the use of these steels in place of iron.

If we turn now to the results of tests, made by Mr. Kirkaldy, of Siemens' mild steel, we find that the mean results for plates of from 0·37 to 0·70 in thickness, annealed and unannealed, are as follows:

	Ultimate strength. Tons per square inch.	Elastic limit.	Extension per cent.
Unannealed, . .	31·02	14·50	23·4
Annealed, . .	28·84	12·84	24·6

From these figures it will be seen that though this material (like that used at Messrs. Fowler's Works) may be very safe, it presents little structural advantage over iron-plates, the limit of elasticity being low, permanent set taking place at as low as 12·84 tons per square inch when the plates are annealed. It is, however, observable that though the extension of this metal reaches a total of 24·6 per cent. it is less

than 11 per cent. annealed, and under 7 per cent. unannealed at a strain of 26·78 tons, thus indicating very considerable toughness and probably greater value as a structural material than that tested by Messrs. Greig and Max Eyth.

Material described still more recently gives the engineer even less of hope that the modern steels for structural purposes will enable him to produce structures much lighter than he can do with iron. It would even appear that greater hope of obtaining a material of high structural value is to be found in iron, for it was recently stated at a meeting of the Iron and Steel Institute by a member, that he had been experimenting with puddled iron, the elastic limit of which ranged from 19 tons to 20 tons, while its ultimate strength was 29 tons and its elongation between these strains was 23 per cent. in a length of 8 inches. The elongation within the elastic limit was not mentioned. Unless a higher elastic limit can be obtained no advantage in a structural sense is secured. High ultimate strength is a comparatively useless quality if the elastic limit is low, and great range of extension is also of no service. In bridge work a very high range of extension is useless, because the members under tension would elongate if strained beyond the elastic limit, to a greater extent than the members under compression would compress, and thus the structure would fail by the destruction of the balance in the disposition of the strains on the different parts. Even if the material showed a range of compression equal to its range of extension this would remain equally true, because in order to secure the necessary resistance to bending or buckling, members under compression must be of greater sectional area than is indicated by the static strain. Thus a higher elastic limit is the first essential in steel for structural purposes. This it appears can only be obtained by making the steel harder, which, by the Bessemer process at least, if not by other largely used processes, it seems cannot be secured without other attendant qualities or properties which make the material difficult to work, and more or less uncertain in its behavior under mechanical treatment. Whether this is really now so, or must continue so, it remains for the steel makers to show, but it does at least seem plain, that even with some of the so-called mild steels a little misgiving is pardonable on the part of the boiler maker, who wonders what he may find in a boiler shop to-morrow where he has left a nearly or quite finished boiler to-night. Not only, moreover, is this mild steel way of getting over the difficulties attending the use

of the strong steels likely to rob engineers of much that the latter material promised, but by the still existing custom of denominating what is really iron by the term steel, we are likely to use the advantages gained by using the harder steels where that has been possible, for already a good deal of so-called steel, in which there is not much more carbon than there is in a Lowmoor bar, is being worked up into steel rails and steel tires. It is true that rails of very hard steel do not wear quite so well as those of a tougher quality, but it remains to be seen whether some of the very mild metal being rolled into rolls to-day may not soon acquire battered heads under the heavy traffic of modern locomotives. Such rails will not laminate, but it is questionable whether splitting will not result from the deformation by battering.

It will have been observed that in this short paper the attention of the writer has been almost wholly confined to references to plates. This has been done because it is chiefly in plates that improvement has to be looked for from the steel maker. With bar steel, the difficulties in manipulation and connection in structures have not been so great as with plates, and failures, whether due to imposed or internal differential molecular strains, have not been so frequent; the sections are less in area and the forms less capable of initiating and transmiting destructive strains. Consequently mild bar steel need not be so ductile as mild plate steel, and hence the structural value of the former is much higher than that of plates, and engineers can use it to advantage. In the course of a very interesting lecture delivered by Dr. Siemens at the Royal United Service Institution in March, 1879, he gave a table showing the results of a series of tests of mild and hard steel bars up to, and slightly beyond, their elastic limit. This table is of great value as affording evidence of the structural value of these bars, and it is to be greatly desired that similar observations should be made on all kinds of modern metallic structural materials. The mild bars to which Dr. Siemens' table refers show a mean elastic limit of 17·37 tons when annealed, though the same bar showed the lowest mean elastic limit of 16·62 before being annealed, and curiously the elastic extension is also greater in the annealed bars, the mean extension in bars 5 feet 0 inches and 4 feet 11 inches, being 0·088 inch and 0·086 inch, the value of *Te* of the bars being by the before-mentioned formulæ, respectively 57·04 and 53·348. This denotes a high structural value although this indication must be taken with the value of *Tr* which cannot be gained from the table referred to. Such material, however,

is not to be had or cannot be safely used in plates, and even in bars has been very little used in bridge work. Steel makers have yet to satisfy engineers that it can be safely used.

The most of the recorded experimental results of tests of mild steels do not give the extension at the elastic limit, so that comparisons with other materials cannot at present be made. From what has been said, however, it will have been seen that it is very necessary that these figures should be obtained, and what has often been observed may be here repeated, namely, that in order to the production of a satisfactory series of tables of the mechanical properties of different structural metals, experiments should be conducted on a uniform basis and with uniform lengths of test pieces, or if not of uniform length, they should be of a minimum length of either ten inches or one foot. Such experiments would be perhaps costly, but there is at least one wealthy engineering society, by a committee of which such experiments might be usefully carried out on the structural materials of to-day.

In conclusion, a few words may be said upon the behavior of the harder kinds of steel plates in which they differ from those of iron. It has been observed by many that some of the steel plates with an elastic strength as high as 18 tons per square inch combined with a ductile extension as high as 15 per cent. as obtained by the tests of strips of such plates, that in the hands of plate-smiths or when built into structures, they behave very differently to iron with the same apparent mechanical properties. The toughness of good iron plates enables them gradually to dissipate any internal differential molecular strains of tension and compression that may be resident in them as they leave mills, by differential compression and tension. Steel plates which are comparatively hard, but, which, when torn asunder in test-strips, indicate an ultimate extension of as much as 15 per cent., might be expected to do the same. Such, however, is not the case, for the plate has often behaved when built up into a structure as though its ultimate extension was not more than one or two per cent., and like glass, possessed of high elastic limit but no toughness. Why this should be is not known, but it may be suggested that such being the behavior, the following may afford some clue to the fact that thick plates, at least of such material, have fractured in various directions, after the structure of which they have formed an integral part has been completed. Most plates before being built into a structure are annealed, but the following remarks apply equally whether annealed or not.

Plates when taken from the rolls or from the annealing oven are generally laid on a flat surface to cool, but whether laid down or stood on edge, cooling takes place somewhat more rapidly towards the corners and edges than at the middle. At first, the whole plate is of the same temperature, which may be that of redness. The exterior parts first assume the rigidity of cold steel, and contraction takes place on the interior parts which remain at a higher temperature, and therefore the contraction has taken place under a tensile strain. Thus, if a plate of 1 inch in thickness is considered in illustration, it will be seen that a corner of, say, 6 inches on either edge, has an area on the two sides of 36 square inches, but it has also the additional effective cooling area of the edges, which adds 12 square inches, making for a surface area of 36 square inches a total of 48 square inches of effective cooling area by radiation and evection. If, on the other hand, an area on the two sides at the centre of the plate, of 36 square inches of such surface, be taken into consideration, it will be seen that the edge surface can only be considered as cooling by conduction. Thus the effective cooling area of the outer parts of the plate is much more efficient than the central parts. These outer parts having, then, become rigid and contracted under tension, exert a correspondingly compressive strain upon the interior parts still at a higher temperature, and thus more or less amenable to compression. This tensile strain upon the outer parts or borders of the plate is gradually eliminated as the interior parts cool, and is finally changed into one of compression as the inner parts contract in cooling under a molecular tensile strain, due to the incapacity of the rigid border to follow the inner parts in the contraction. In the cold plate put into a structure, there is thus initial molecular strain differentiating from compression at the edges to tension towards the centre. If the plate is cooled under circumstances inducing unequal cooling, these internal strains are aggravated, and they may possibly be of such magnitude that extraneous strains, that would not materially affect a tough iron plate, may be sufficient in a harsh steel to cause rupture. Further, when a plate of such a character is being riveted up, every rivet is compressed under a very high strain to make it fill the holes, and thus acting as a viscous fluid, adds to the strains already tending to destroy the plate.

These remarks are only made as suggestions, and should perhaps have been put in the form of a question, as they are somewhat aside the object of this note, which is to invite discussion on what seems to

be the tendency in the production of very mild steel plates, namely, that in the endeavor to remove the difficulties which have attended the use of steel plates of high elastic limit, we seem to be in danger of losing the facilities for producing lighter structures which the application of steel seemed at one time to afford.

ON A PECULIAR BEHAVIOR OF COPPER.

By W. H. Preece.

Read before the British Association at Swansea, August, 1880.

In the preliminary experiments with the copper conductor, made by Dr. De la Rue and myself, to get everything in working order, it was noticed that in each case the effect of the first discharge was considerably smaller than in the subsequent ones, leading to the conclusion that the resistance of the conductors was affected by the powerful currents sent through them. The difference was so marked that no variation in the electromotive force of the battery or in the capacity of the condenser would account for it. Moreover, all the connections were so carefully made that nothing could account for the change but a variation in the resistance of the conductors.

Experiment 1.—A piece of ordinary gutta-percha covered wire, 30 feet long, was first used as a shunt to the galvanometer. A delicate Thomson's reflecting galvanometer (whose resistance was 5270ω) was joined up in circuit with a single cell of a battery, and a resistance of 100ω. Discharges were then sent through the wire, and the latter, after each discharge, connected to the galvanometer. No difference was observed in the readings taken before and after the discharges. Any alteration in the resistance, however minute, would have been visible in the readings of the galvanometer. The wire had been used for other purposes, and weak currents had been through it before. Hence it was thought that the effect might be evident only in virgin copper, that is, copper through which no current had previously passed.

To test this, three pieces of virgin copper wire—0·029, 0 049, 0·071 inches diameter—were obtained direct from the manufacturers, and used as shunt to the galvanometer previous to and after conveying the

powerful currents resulting from the discharge of 42·8 mf., charged by 3280 cells.

Experiment 2.—0·071 inch wire:

Previous to discharge,	210°
After first discharge,	210
" second "	173
" third "	153
" fourth "	150

The change was very marked.

Experiment 3.—0·049 inch wire:

Previous to discharge,	440°
After first discharge,	440
" second "	440
" third "	440
" fourth "	440

No change was observed.

Experiment 4.—0·029 inch wire (200ω resistance in circuit):

Previous to discharge,	630°
After first discharge,	630
" second "	615
" third "	615
" fourth "	610

Change was very slight.

Experiment 5.—The same experiments were performed with lead conductors, but without perceiving any change. Hence, while a considerable change of resistance was observable, the effect was very variable. The fact, however, is evident, that in some cases copper wire does not acquire its normal resistance until currents have passed through it. No definite conclusion or measurable results can be obtained from these experiments. Nevertheless, the phenomena were so decided and peculiar, that Dr. De la Rue and I propose to pursue the inquiry when foreign travel and seaside rest have restored our waning energies and replenished our scientific ardor.

ON THE LIQUEFACTION OF OZONE, AND ON ITS COLOR IN THE GASEOUS STATE.

By MM. P. HAUTEFEUILLE and J. CHAPPUIS.

Ozone, as commonly prepared, possesses in oxygen so small a tension, 53 mm. at most, that its physical properties are scarcely known and distinguished from those of oxygen. We know the difficulties which M. Soret has so skillfully overcome in determining the density of ozone by operating upon oxygen slightly ozonized.

Among the physical constants of this body its formation-heat has been accurately determined by M. Berthelot, notwithstanding the degree of dilution in which it occurs when issuing from the effluve apparatus. The preparation of a mixture very rich in ozone is the first condition to be fulfilled in order to acquire new notions concerning this curious substance. We have formerly established that the isomeric transformation of oxygen submitted to the electric effluve follows simple laws, and that the proportion of ozone increases very little with the pressure for each temperature, whilst it is quintupled in passing from 20° to —55°. If withdrawn from the action of the electric discharges the mixture of ozone and oxygen ceases to be a homogeneous system in equilibrium. Nevertheless the mixture remains without appreciable alteration during the whole time that a constant temperature is maintained, operating below 0°. This relative stability of ozone has enabled us to compress the mixture, and to obtain tensions of ozone of several atmospheres.

As it is necessary to prepare the ozone designed for these experiments at the highest tension possible, oxygen must be ozonized at a very low temperature. Consequently it is kept for a quarter of an hour in an apparatus for alternative discharges, the slender concentric glass tubes of which are plunged in methyl-chloride; then it is caused to pass into the cylinder terminated by a capillary tube of Cailletet's apparatus. This reservoir, of about 60 cc. capacity, originally a vacuum, and kept at —23°, cannot be filled at once under a pressure bordering upon 760 mm., and is rapidly connected 5 times in succession with the effluve apparatus, the capacity of which cannot exceed 20 cc. In an hour and a quarter we succeed by this means in filling

the cylinder with a mixture of oxygen and ozone very rich in the latter gas.

The cylinder is then taken out of the methyl-chloride, and separated from the effluve apparatus by a stroke of the file; the gas which it contains is slowly driven back by means of mercury cooled down to 0° into the capillary tube, which is kept a —23°.

The mercury which transmits the action of the hydraulic press does not impoverish the gaseous mixture as rapidly as might be apprehended; there is formed on the surface of the metal a solid varnish, which rapidly limits the action; the heating of the gas during compression is more to be feared. Notwithstanding these difficulties we succeed in increasing the tension of the ozone in a very high proportion. From the first strokes of the piston the capillary tube becomes a sky-blue. This coloration becomes more marked in proportion as the volume of the gas is reduced, and if the tension of the gas is brought by compression to several atmospheres the gas is an indigo-blue, and the meniscus of mercury, seen through the gas, a steel-blue. The blue color of the gas becomes less intense, and the mercury resumes its ordinary metallic aspect when the tension of the ozone is diminished.

The above mixture contains enough ozone to permit the observation of a dense white mist at the moment of release after a compression of 75 atmospheres. It is therefore not necessary to compress ozonized oxygen as much as pure oxygen (300 atmos.), in order that a sudden release may occasion the momentary formation of a mist, the certain sign of liquefaction or even solidification. A comparative study of mixtures of oxygen and ozone, and of oxygen and carbonic acid, shows that under conditions which are fairly comparable the release must be stronger for ozone than for carbonic acid in order to make a mist appear. Ozone is therefore a little less easily liquefied than carbonic acid.

The mixture of oxygen and ozone, being an explosive gas, should always be compressed slowly and refrigerated. If these conditions are not observed the ozone is decomposed with the liberation of heat and light, and there is a strong detonation attended with a yellowish flash. M. Berthelot has shown that the transformation of oxygen into ozone absorbs 14·8 cals. per equivalent ($O_3 = 24$ grms.). Ozone therefore ranks among the explosive gases, and our experiments show that like them it is capable of a sudden decomposition. A part of these new facts may also be observed in oxygen which has been passed slowly

at common temperatures through an effluve apparatus. For if the gas is rapidly compressed in a capillary tube placed in water at 25° the ozone is often destroyed with explosion. But if the same gas is cooled down to —23° the ozone which it contains may be brought to a tension of 10 atmospheres, and may be preserved for hours under these conditions of pressure and temperature if the gas is separated from the mercury by a column of sulphuric acid. We observe then almost as distinctly as in the former experiment, which is more difficult to perform, that ozone is a gas of a beautiful sky-blue. Its color at a tenfold density is so intense that we have been able to see it in a tube of 0·001 metre in diameter when operating in a very badly lighted room of the laboratory of the Ecole Normale.

It is therefore ascertained that under a strong pressure ozone is a colored gas, but is it the same with ozone at the tension of a few millimetres? The blue color is as characteristic of ozone as its odor, for at all tensions it is recognized on examining a stratum of the gas of sufficient depth. In order to render it apparent it is merely needful to interpose between the eye and a white surface a tube of 1 metre long traversed by the current of oxygen which has passed through Berthelot's effluve apparatus. The color of the gas then resembles that of the sky, and is deeper or lighter according as the oxygen has remained a longer or shorter time in the apparatus, and is consequently more or less rich in ozone. As soon as the effluve is interrupted the blue color disappears, the ozonized oxygen being replaced by pure oxygen.—*Comptes Rendus.*

Siphons in Sewers.—In constructing sewers it is often necessary to lead them across the branch of a river or some other water course. The passage has usually been accomplished on the plan of M. Belgrand, by means of a submerged siphon. The sunken portion, however, often clogs, and even where Belgrand's cleansing sphere is introduced the visits and repairs are difficult and costly. Maurice Lœvy has introduced an elevated siphon, to carry the sewer waters from Bercy over the St. Martin canal. Water pipes and valves are connected with the summit of the siphon in such way as to act automatically whenever the movement of the sewage becomes sluggish, and the experiment has proved satisfactory and economical.—*Ann. des Ponts et Chauss.* C.

IMPROVEMENTS IN NICKEL-PLATING.

In nickel-plating the double salts of nickel and ammonia are generally employed—either the sulphate or the chloride—but these are not exactly satisfactory, and amongst recent improvements we notice those of Mr. J. Powell, of Cincinnati, which consists in forming nickel-plating solutions, whereby the difficulty of electrolysing certain acid or neutral nickel salts is entirely overcome. It is well known to electro-platers and others versed in the art, that the double salts of nickel as commonly used, such as the double sulphate of nickel and ammonia, or the double chloride of nickel and ammonia, or the double sellenate (*sic*) of nickel and ammonia, and other similar double salts, become altered in their proportions and undergo various changes dependent upon the power of the electric current or the length of time during which the solutions are subjected to its action. These changes are particularly liable to occur in such alkaline or neutral solutions as contain ammonia, from the fact that the ammonia is given off as a gas on the terminal poles in the solution. On the other hand, the simple acid salts of nickel have not hitherto been found to answer for the purpose of electro-deposition from the fact that such solutions refuse to yield a reguline or cohesive deposit of metallic nickel, but, on the contrary, such nickel solutions as the sulphate, the acetate, the sellenate, the chloride, the tartrate, the citrate and kindred salts invariably yield under the influence of the electric current a deposit more or less grey, powdery, or black, and having no adhesiveness or ductility whatever. This seems to be caused by the evolution of hydrogen and the deposit of a suboxide or subchloride, or other subsalts along with a certain proportion of metal. Mr. Powell has discovered by a series of investigations and experiments that the addition of benzoic acid to any of the salts of nickel (especially when a solution free from alkali is used) corrects in a marked degree this tendency to an imperfect deposit, and prevents the evolution of hydrogen, chlorine, oxygen, nitrogen and carbon, and consequently the formation of the subsalts referred to, and that which previously was wholly worthless as a depositing solution, and yielded a black powdery metal unfit for any practical purpose, when properly combined with benzoic acid, will then give a tough, cohesive and reguline deposit of a beautiful silvery-

white metallic nickel. The patentee has discovered, also, that such a solution becomes more stable in its character, the solution of the anodes keeping pace with the rapidity of the deposit, thus maintaining a constant density of the liquid under varied conditions of work. The amount of benzoic acid to be added is not arbitrary, but may vary from one-eighth of an ounce to one ounce of acid to each gallon of the solution, according to the nature of the solution employed; or the benzoic acid may be displaced by the "benzoates," as, for instance, the benzoate of nickel. The inventor has discovered, also, that benzoic acid is equally valuable as an ingredient in the solutions of other metals, as, for instance, the salts of cobalt, manganese, etc. He does not confine himself to any precise formula, so long as benzoic acid or its compounds makes a constituent of a depositing solution; but he prefers, among others, the following: To one gallon of pure water add 4 ounces of sulphate of nickel, 3 ounces of citrate of nickel, 1 ounce of benzoic acid; or the following formula may be used: To one gallon of pure water add 2 ounces of chloride of nickel, 2 ounces of citrate of nickel, 2 ounces of acetate of nickel, 2 ounces of phosphate of nickel, 1 ounce of benzoic acid; or the following: 3 ounces of sulphate of nickel, 3 ounces of citrate of nickel, 1 ounce of benzoate of nickel, ¼ ounce of free benzoic acid; or the following: 3 ounces of acetate of nickel, 3 ounces of citrate of nickel, 1 ounce of phosphate of nickel, 2 ounces of pyrophosphate of soda, 1 ounce of bisulphite of soda, 5 ounces of aqua ammonia, 16 per cent. The benzoic acid being sparingly soluble in water it is advisable to heat the other nickel salts in the proportion of water named, and then, while boiling hot, add the benzoic acid, which will in this state combine with the nickel salts in a greater degree than with water alone. A great advantage obtained from the use of the above described solutions arises from the fact that the necessity of using chemically pure salts or ingredients is dispensed with. In preparing the sulphate, citrate, acetate or chloride of nickel, it is preferred to take the common commercial acids to dissolve the nickel base because of their cheapness, the otherwise injurious effects caused by impurities always contained in said commercial salts or acids being entirely overcome by the addition of benzoic acid as stated. The patentee is thus enabled to produce nickel-plating solutions at a much less cost than has heretofore been attainable. It is obvious that these improved solutions are equally applicable to the deposition of nickel in the electrotype process, by which the metal is caused to deposit over

surfaces made conducting by means of a thin film of plumbago, bronze powder, etc., applied in the usual manner well known to electrotypers and others skilled in the art, the deposit so made being removable from the surface, mould or matrix after the requisite degree of thickness has been obtained. In such nickel-plating solutions as contain ammonia or other alkaline salts, it is preferred to combine with these, as giving the best results, the pyrophosphate of soda and the bisulphite of soda, because it has been discovered that the addition of these salts prevents the destructive decomposition to which such solutions are liable. Finally, salicene or salicylic acid and gallic or pyrogallic acid may be added to or substituted in any suitable proportions for the benzoic acid.—*English Mechanic.*

Safety Paper.—A bank in Lyons uses a paper which is colored with ultramarine green. The bills of exchange are lithographed, and the figures are written with an acidulated ink, so as to appear white upon a green ground. This seems to furnish a perfect security against alterations.—*Dingler's Journal.* C.

Electric Light in the French Salon.—The Palais de l'Industrie was lighted by the Jablochkoff method during the recent exhibition. There were 356 candles in all, the motive force being supplied by five engines and twenty Gramme machines. The effect upon the sculptures was uniformly pleasing. Some of the painters complained that the electric light made their pictures look unnatural by falsifying the colors, but while some of the paintings lost effect others gained it. The general public were so well satisfied as to throng the Salon in crowds every evening.—*Les Mondes.* C.

Maiche's Electrophone.—Experiments have been recently made in France with a new electrophone. A small glass case is enclosed in a wooden box. Upon the glass there are small cylinders of pure charcoal, and the vibrations are transmitted by a single telegraphic wire. The return current by the earth gives a better result than when two wires are employed. No mouthpiece is required, it being sufficient to speak in the neighborhood of the instrument. The inventor is confident that he will be able to send messages by the transatlantic cable between France and America.—*Ann. du Gen. Civ.* C

Magnesium in the Sun.—The intensity and the frequency of reversal of the magnesium rays, in the green region of the solar spectrum, has long attracted the attention of spectroscopists. It has also been observed that the reversal did not affect all the rays at the same time. Prof. Young has made extensive comparisons with the C ray of hydrogen, which is always reversed in the chromosphere; Lockyer has shown that the reversed rays are the longest, and that among the reversed rays that which is the least intense is also the shortest; Tacchini measures the variations of solar activity by the number and frequency of reversals, supposing that the most intense rays appear first and that the energy of the eruptions varies in proportion to the number of reversals. This inequality of reversal has led to the theory that all terrestrial elements are dissociated in the sun into other unknown elements which have more simple spectra than those which are known. This theory implies the impossibility of deducing the constitution of celestial bodies from the spectral study of terrestrial elements until they have been dissociated and their component elements have been recognized. Fievez has studied the spectra in various ways. He first examined the influence which the relative intensity of the brilliant magnesium rays exercised on their visibility by projecting them upon the solar spectrum and thus effecting a true reversal. He then repeated his experiments upon the simplification of spectra by varying the intensity of the spark. Finally, guided by Lord Rayleigh's investigations in spectral optics, he studied the influence of a dispersion and of a definition, more or less considerable, upon the number and visibility of the rays, by comparing prismatic and diffraction spectra. His experimental arrangements were the same as those which he adopted in his investigations upon the spectra of hydrogen and nitrogen. They seem to establish conclusively his opinion that a modification in the appearance of the spectrum springs from a physical cause and not from a change in the chemical constitution of the metal or or a dissociation, and that the unequal reversal of the magnesium rays is caused by a difference in the intensity of the brilliant rays and not by any special state of the metal.—*Bull. de l'Acad. de Belg.* C.

Punching Iron.—Tresca's experiments upon the flow of solids, and the experiments upon cold punching by Messrs. Hoopes and Townsend and Prof. Thurston, have induced Prof. Keller to make a

series of experiments in the machine shops of Carlsruhe. The pieces, after being punched, were cut and the surfaces treated with a solution of chloride of platinum in water, containing one part of the chloride for 250 to 300 parts of water in volume. The employment of this solution brings out the lines of flow in brown upon a ground of brilliant gray. The operation of punching is divided into two distinct periods. The first begins with a depression at the top, the displaced matter being carried towards the bottom in such manner that the sides, which are at first vertical and parallel, soon incline towards each other. In proportion as the punch advances the material turns towards the point of least resistance, forming a sort of button underneath, the height of which is always much less than the depth to which the punch has penetrated, showing that the metal has either been compressed or that it has been driven laterally into the body of the piece. Keller found by experiment that the specific gravity of the plug was a little less than that of the residue. This fact had been observed by Hoopes and Townsend, but they attributed it to errors of observation. If the plug is cut into sections the density is found to increase towards the top, showing that there is a flow from underneath the punch laterally into the mass of the iron. In the second period, or period of chiseling, the resistance is less; there is no more compression and the plug goes out in proportion to the descent of the punch until the separation is complete. By equating the resistance to compression at the end of the first period to the resistance to chiseling at the beginning of the second the author found for iron the following formula:

$$C = \frac{\delta^3}{1{\cdot}15}\left(1 - 1{\cdot}3\,\frac{D}{\delta} + 0{\cdot}42\left(\frac{D}{\delta}\right)^2\right)$$

in which C is the total apparent compression, D the diameter of the punch and δ the thickness of the plate. The work expended in punching, when referred to a square millimetre of cylindrical surface of the hole, was satisfactorily represented by Hartig's empirical formula

$$a = 0{\cdot}25 + 0{\cdot}0145\,\delta.$$

—*Bull. de la Soc. des Ing. et Arch. d'Autr.*

Printing Cable Dispatches.—Marquis Tomasi has succeeded in printing, with plain alphabetic letters, dispatches which had crossed the ocean by the trans-Atlantic cable, using only two cells of a Dinotto battery. There are still some irregularities and difficulties, which he hopes soon to overcome.—*Les Mondes.* C.

Organic Synthesis.—About fifty years ago Woehler discovered that benzoic acid, when introduced into the digestive tube of man or animals, was transformed into hippuric acid. Other syntheses in the animal economy have been more recently discovered, and Baumann has recently shown that phenol and a number of other similar compounds are transformed into acid ethers.—*Ann. de Chim. et de Phys.* C.

Velocity of Steam Engines.—Prof. Von Reiche recommends as the most suitable velocity for the piston, $v = \sqrt{p}$, p representing the absolute initial tension in atmospheres behind the piston. Prof. Werner recommends $v = 4{\cdot}2\sqrt{s}$ for high pressure engines, and $v = 3\sqrt{s}$ for condensing engines, s being the length of piston stroke. The latter rule appears preferable, because the most suitable piston velocity is greater in large engines than in small, under all circumstances, even when p has the same value. Gustav Schmidt recommends the equations $v = \frac{n\,s}{30}$ and $v = a\left(10 + \sqrt{N}\right)$; N being the effective horse power. The coefficient a varies with the rapidity of the motion of the engine, ·05 being very slow, ·07 slow, ·09 normal, ·11 quick, ·13 to ·20 very quick. Therefore, for a fifteen horse-power engine $v = 1{\cdot}25$ metres, while for a 150 horse-power engine $v = 2$ metres, at the normal velocity.—*Dingler's Journal.* C.

Philosophy of Welding.—If iron were similar to other bodies, and a blow or sudden pressure produced heat all through the mass, the unexpanded liquid at the surface, as well as the interior plastic iron already expanded, would rise in temperature, the consequence of which would be that the molecular conditions at the junctions would still differ, although both at a higher temperature, and therefore molecular union could not take place. But if the liquid iron at the surface of the weld is in that condition of temperature that it would cool by pressure, the result is different, as the blow or pressure acts on the plastic iron to produce heat, and on the surface iron—which is on the border-land between liquidity and plasticity—to produce cold; consequently there is a moment when the temperatures of the two would meet each other and render the molecular condition of the junction uniform and continuous. This appears to be a satisfactory explanation of the wonderful property of welding iron, and its counterpart in ice is the interesting phenomenon of "regelation."*L'Ing. Univ.* C.

Electric Adhesion of Metal Contacts.—A. Stroh has experimented upon the adhesion of two metals in mutual contact during the passage of an electric current. The adhesion is manifested most strikinly when the metals touch upon two edges crosswise; it changes with the nature of the metal. Stroh attributed the adhesion to a superficial melting and welding, which can be perceived by a microscope.—*Dingler's Journal.* C.

Human Power for Short Intervals.—At a late national trial of fire engines Prof. Hartig made some valuable experiments upon the amount of strength that could be exerted, for a short period, at the engine bar. The engines were worked by foot soldiers, on a warm day, and under an exposure to the direct rays of the sun. The mean velocity of the handles was 1·77 metres per second; the mean value of the effective work for each man 22·58 kilogrammetres per second, or about 4·1 times the value which Morin and Weisbach assumed for the average of eight hours' continuons labor.—*Dingler's Journal.* C.

Heats of Combustion.—Herr Thomsen has published in the proceedings of the Berlin Chemical Society the results of his experiments upon the heat of combustion of carbonated gases and of cyanic compounds. These publications are posterior to those which were made by Berthelot. and they confirm in a remarkable manner the results which were obtained by the French chemist. They are specially important in consequence of their having removed the last traces of the error which had been made in estimating the heat of formation of ammonia and, consequently, of all other bodies which are associated with it.—*Comptes Rendus.* C.

Collodion Tablets. — Schippang and Wehenkel dissolve gun cotton in the usual way in ether and alcohol, evaporate the solvent and press the residuum into tablets, under a pressure of about two atmospheres. These plates, which are called *collodolith*, resemble glass in appearance, burn slowly when they are held in a flame, and resist all atmospheric influences. Sometimes iodine and bromine salts are mixed with the collodion. Many of these plates are laid upon one another and then wrapped in sheets of pure collodion so as to be protected against external influences. This iodocollodolith can be used at any time for photographic purposes.—*Dingler's Journal.* C.

Franklin Institute.

HALL OF THE INSTITUTE, October 20th, 1880.

The stated meeting was called to order at 8 o'clock P.M., the President, Mr. William P. Tatham, in the chair.

There were present 105 members and 16 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced that two persons were elected members of the Institute at their last meeting.

The Secretary reported the following donations to the Library.

British Patents. Vols. 22 to 33. 1879.

British Patents. Abridgments relating to Carriages. 1625 to 1866. London, 1880.

British Patents. Abridgments relating to Farriery. Part 2. 1867 to 1876. London, 1880.

British Patents. Abridgments—Electricity and Magnetism, Div. 4. Parts 1 and 2. 1839 to 1876. London, 1880.

Disclaimers of Patents. 1872, No. 916; 1873, No. 1040; 1877, No. 4647; 1878, Nos. 563, 624, 729; 1879, Nos. 57, 1226, 2447, 3230. From the Commissioners of Patents, London.

Textile Manufacturers' Directory of the United States. 1880. From National Association of Wool Manuf., Boston.

Aids to the Study and Forecast of the Weather. By W. C. Ley. London, 1880.
From the Meteorological Committee of the Royal Society.

United States Coast and Geodetic Survey. Methods and Results on a Physical Survey of the Delaware River. From the Survey.

Reports of the Secretary of War for 1874. From the Secretary.

"Gregory's Perfect Combustion Furnace" was exhibited in model and by diagrams on the screen. Mr. C. H. Towne described the action of the furnace, the chief feature of which was an arrangement of air passages leading to the point of exit of the gases of combustion from the furnace, the inventor claiming that by furnishing a full supply of oxygen under these conditions perfect combustion was secured. The coal is continuously fed to the combustion chamber through a hopper. Mr. Towne stated that the inventor had an experimental furnace built on

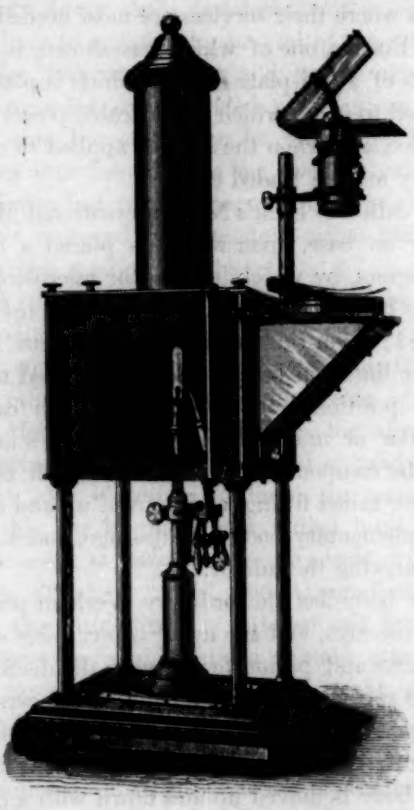
this principle, in which refuse coal, rubbish of all kinds, garbage, etc., had been consumed without smoke or offensive odors, showing perfect combustion. Economy was claimed on this account, but Mr. Towne, in answer to questions, said that he could give no precise data showing the results obtained.

Mr. Nystrom volunteered to explain the diagram, showing how the heat developed could be utilized under a boiler or to warm houses, a point not mentioned by Mr. Towne. He said that the idea of the furnace was not entirely new, similar forms being now in use for making steam, though the arrangement of parts was not the same.

Mr. Hector Orr exhibited samples of Toye's Multitint Printing, and briefly described what he considered a very important invention. He said that it could be applied to the printing of paper, cloth, morocco, etc., and used for decorating sheet metal, fancy woods for mosaic tables and various other substances which it might be desirable to ornament in large quantities. In this invention we have the means of drawing fresh tribute to Philadelphia, and the Institute could trust the inventor, now that the principle had been shown to be right, to perfect the machines that might be needed to apply it to any desired end. The samples of multitint printing shown by Mr. Orr were marbled surfaces of paper and cloth, in various colors, and used as the groundwork for printing cards, etc.

The Secretary's report includes an account of Queen's new College Projector, which is an optical lantern in its most perfect form, combining the horizontal and vertical positions, and especially adapted for the illustration of the laws of light, sound, and for chemical experiments. To accomplish this, the brass body is rigidly held together by thumb-screws at the top, and is supported on four pillars, at an elevation of about one foot, fitting it for the reception of either an electric lamp or an oxyhydrogen lime jet. The brass body is 11 inches long, 9 high and 8 wide, and is furnished with doors on either side, and a tall chimney to carry off any heat. To the front inside is attached the collecting lens of the condenser, the condensing lens being set in a collar on the flap or door hinged on the outside. This collar supports a bar, carrying the object glass and one of Foucault's mirrors, all being capable of being rotated around the optical axis of the instrument. When it is used as a vertical lantern, the flap is raised to a horizontal position, and is supported by the brass prism inclosing the reflector. All the optical combinations have been determined, after

long and careful experiment, so as to project a sharp, well defined and flat image on the screen. As the oxyhydrogen jet is specially adapted, also, to the focus of this lantern, an excellent illumination is obtained.



To show the qualities of the projector, a set of Kœnig's wave apparatus plates were exhibited. These glass disks, with black surfaces, have lines traced upon them, in such a way that when revolved before the lantern (a metallic screen, with a number of fine vertical slits, being interposed) wave motions of condensation, rarefaction, etc., were reproduced in moving points of light, in the most perfect way, upon the screen.

Harris' Fire Escape and Hose Elevator, a model of which was shown, consists of a suitable carriage and three ladders, which are supported in the vertical position when in use by bridges, at different

heights, resting on them. The outer ones are hinged to the carriage, and all three ladders readily lie upon it when not in use. The hose is also easily elevated to any particular point, and the firemen can pass on the bridges to where their services are most needed.

Dwight's Car Pusher, one of which was shown, is made entirely of steel, and consists of a bed-plate or shoe, which is placed on the track, and a lever hinged to it, by which considerable power is obtained. It will not slip on ice, and when the lever is applied to one of the wheels a man can readily move a loaded car.

Attention was called to Beck's New International Microscope, which has a tripod for its base, upon which is placed a revolving fitting, graduated to degrees, by which means the microscope can be turned round without its being lifted from the table, and the amount of such rotation registered; upon this fitting two pillars are firmly fixed, and between them the limb can be elevated or depressed to any angle, and tightened in its position by a lever. The limb carries at one end the tube (binocular or monocular), with eye-pieces and object-glasses. In its centre is the compound stage, beneath which is a circular plate, sliding on a dove-tailed fitting, and moved up and down by a lever, carrying the supplementary body or sub-stage, and at the lower end a triangular bar, carrying the mirror.

The binocular body has the ordinary Werham prism, for the purpose of dividing the rays, and the upper or eye-piece ends of the tubes are fitted with racks and pinion for varying the distances between the two eye-pieces, to suit the differences between the eyes of various persons, and arrangements are made for racking out one tube more than the other, to suit irregularities or inequalities between the eyes of the observer. This body is moved up and down with a quick movement, by means of milled heads, and also with a very delicate and fine adjustment. This milled head works against a lever, which moves a slide independent of the rack-movement, and gives an adjustment at once certain and decided.

The compound stage is of an entirely new construction; the object is most frequently merely placed upon it, but, if necessary, it can be clamped by carefully bringing down a spring-piece. The ledge will also slide up or down, and the object may be pushed sideways. This arrangement forms the coarse adjustment. Finer movements in vertical and horizontal directions are effected by means of two milled heads, the screws attached to which are kept up to their work by

opposing springs, so as to avoid all strain or loss of time. The whole stage revolves in a circular ring by a milled head, or this can be drawn out, and then it turns rapidly by merely applying the fingers to the two ivory studs fastened on the top plate, which is divided into degrees to register the amount of revolution. The stage is attached to the limb on a pivot, and can be rotated to any angle, which angle is recorded on a divided plate or can be turned completely over, so that the object can be viewed by light of any obliquity without any interference from the thickness of the stage.

Beneath and attached to the stage is an iris diaphragm, which can be altogether removed from its dove-tailed fitting, so as not to interfere during the rotation of the stage. The variations in the aperture of this diaphragm are made by a pinion working into a racked arc and adjusted by a milled head.

Beneath the stage are two triangular bars, the one revolving round and the other rigid in the optical axis of the instrument. On the former the sub-stage, carrying all the apparatus for illumination and polarization, fits, and is racked up and down by a milled head; the mirror, also, if desired, slides on the same bar; the revolving motion to this bar is given by a milled head, and the amount of angular movement is recorded on the circle, whilst the whole of this part of the stand is raised and lowered concentric with the optical axis of the instrument by a lever and the amount of such elevation or depression registered on a scale attached to the limb. This bar can be carried round and above the stage, and be thus used for opaque illumination.

The lower triangle bar carries the mirror or a right-angle prism, when the illumination is required to be concentric with the optical axis of the instrument, and independent of the movements of other illuminating apparatus.

The mirror-box contains two mirrors, one flat and the other concave; it swings in a rotating semicircle attached to a lengthening bar, which enables it to be turned from one side to the other, and revolves on a circular fitting for giving greater facilities in regulating the direction of the beam of light reflected, the whole sliding on either of the triangle bars, previously referred to, and made to reverse in the socket so as to bring the centre of the mirror concentric with the axis of the microscope in either case.

As the mirror alone is insufficient for many kinds of illumination,